Expert Report of Professor James L. Sweeney

Submitted August 13, 2018

Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,
v.
The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

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I. Qualifications

1. I, James L. Sweeney, am an economist at Stanford University. I have focused my professional activities on economic policy and analysis, particularly in energy, natural resources, and the environment, and am currently concentrating on energy efficiency.

2. At Stanford, I am a professor of management science and engineering. In addition, I am a senior fellow of the Hoover Institution, the Precourt Institute for Energy, and the Stanford Institute for Economic Policy Research.

3. Also at Stanford, I have served as chairman of the Department of Engineering-Economic Systems and as chairman of the Department of Engineering-Economic Systems and Operations Research. I served for eight years as a member of the Executive Committee of the Stanford School of Engineering. I have also served as the Director of the Energy Modeling Forum ("EMF"), the Chairman of the Institute for Energy Studies, and the Director of the Center for Economic Policy Research (now named the Stanford Institute for Economic Policy Research). I was founder and until recently, the director of the Precourt Energy Efficiency Center.

4. I have taught courses at Stanford on "Economics of Natural Resources," "Energy and Environmental Policy Analysis," "Economic Analysis," "Engineering Economics," and "Policy and Economics Research Roundtable."

5. Outside of Stanford, I have served on the editorial boards of *The Energy Journal* and *Resource and Energy Economics* and have served as co-editor of *Resource and Energy Economics*. In the early 1970s, I served as Director of the Office of Energy Systems Modeling and Forecasting of the United States ("U.S.") Federal Energy Administration. In that role I was responsible for the development and application of the energy supply and demand models the federal government used to forecast future energy conditions and was extensively involved in the analysis underlying energy policy making in the 1974–1976 period.

6. I am also a Senior Fellow of the U.S. Association for Energy Economics ("USAEE") and have received the Adelman-Frankel Award from the USAEE for unique contributions to energy economics. I am a founding member of the International Association for Energy Economics

("IAEE") and have received the 2008 award from the IAEE for Outstanding Contributions to the Profession of Energy Economics and to its literature. I am a senior fellow and chairman of the Council of the California Council on Science and Technology, and a member of the External Advisory Council of the National Renewable Energy Laboratory. I was founding chair of the Petroleum Market Advisory Committee, advising the California Energy Commission.

7. I periodically give talks in the U.S. and other countries (e.g., China, Singapore, South Korea, Japan, New Zealand, Australia, Turkey, U.K., and Norway) on energy efficiency and its role in reducing greenhouse gas ("GHG") emissions and global climate change. For the last 10 years I have been one of the three co-conveners of the annual international conference "Behavior, Energy, and Climate Change." I annually convene the Silicon Valley Energy Summit at Stanford, which aims at making Silicon Valley organizations and communities more sustainable, clean, efficient, and productive. For the last 20 plus years, I have been an annual participant at and contributor to the Snowmass Workshop on Climate Change Impacts and Integrated Assessment, which integrates scientific knowledge of the numerous impacts of global climate change.

8. I have been a member of numerous committees and boards of the National Research Council, including the Committee on Benefits of Department of Energy ("DOE") R&D in Energy Efficiency and Fossil Energy, the Committee on Effectiveness and Impact of Corporate Average Fuel Economy ("CAFE") Standards, the Committee on Alternatives and Strategies for Future Hydrogen Production and Use, the Committee on America's Energy Future, the Board on Energy and Environmental Systems, and the Board on Environmental Change and Society.

9. I was co-chair of the transition team task force that developed the energy policy framework for Governor Schwarzenegger's first administration, and I served as a member of Governor Schwarzenegger's Council of Economic Advisors. I was also a member of the Economics and Allocation Advisory Council of the California Air Resources Board, providing recommendations to the State of California regarding implementation of the cap-and-trade system for greenhouse gases for the State.

10. I periodically serve as an advisor to the California government, the Natural Resources Defense Council ("NRDC"), several clean energy startups, and other energy companies, in

addition to the federal government. I have served as an expert witness in litigations in the U.S. and in New Zealand, and I have testified in state and federal courts. I have provided expert testimony in cases involving royalties, utility regulation, contract disputes, securities, taxation, and antitrust issues.

11. My articles have appeared in numerous books and journals, including: *Econometrica, Journal of Economic Theory, Journal of Urban Economics, Management Science, Resources and Energy, The Bridge, The Energy Journal*, and *Proceedings of the National Academy of Sciences*. I have authored or edited seven books, in addition to the five National Academy book-length studies of which I was a co-author. One of these books, *The California Electricity Crisis*, published in July 2002, is an analytical history of the economic and policy issues associated with California's electricity restructuring and the subsequent crisis. My most recent book, *Energy Efficiency: Building a Clean, Secure Economy*, was published by Hoover Institution Press in 2016; the Chinese translation was published in 2017.

12. I hold a B.S. degree from the Massachusetts Institute of Technology in Electrical Engineering and a Ph.D. from Stanford University in Engineering-Economic Systems. A copy of my curriculum vitae is attached as Appendix A. A list of my testimony from the last four years is attached as Appendix B.

II. Background and Assignment

13. Plaintiffs in this matter state that global climate change is an important problem that has led and will lead to impacts that will be harmful to the well-being of the U.S. population,[1] and that fossil fuel combustion is an important contributor to climate change.[2]

14. Plaintiffs allege that the Defendants[3]—various U.S. government agencies and the public officials managing these offices—have endangered Plaintiffs' health and welfare and have

[1] First Amended Complaint for Declaratory and Injunctive Relief, *Kelsey Cascadia Rose Juliana et al., Plaintiffs, v. The United States of America et al., Defendants*, 9/10/2015 ("Complaint"), ¶1.
[2] Complaint, ¶202.
[3] Defendants include the United States of America, the President of the United States, the Office of the President of the United States, Department of Energy, Department of the Interior ("DOI"), Department of Transportation, Department of Agriculture ("USDA"), Department of Commerce, Department of Defense ("DOD"), Department of State, and United States Environmental Protection Agency ("EPA"). See Complaint, ¶¶98–130.

violated Plaintiffs' rights under the Fifth and Ninth Amendments of the U.S. Constitution through (i) affirmative regulatory acts, including subsidies, tax policies, permits for fossil fuel extraction from public lands, and other acts that increase fossil fuel consumption and cause GHG emissions; [4] (ii) inaction and failure to develop policies to eliminate the use of fossil fuels and mitigate GHG emissions;[5] and (iii) GHG emissions arising from the government's direct consumption of fossil fuels (collectively, "the conduct at issue").[6]

15. Further, Plaintiffs allege that Defendants have "acted with deliberate indifference to the peril they knowingly created."[7] Plaintiffs allege that Defendants have known since at least 1990 that fossil fuels are the primary cause of climate change, and that climate change poses "unusually dangerous risks" and "imminent dangers," yet have "ignored [the advice of] experts" and "continued their policies and practices of allowing the exploitation of fossil fuels."[8]

16. Plaintiffs have submitted the expert report of Professor Joseph E. Stiglitz, who claims to "analyze from an economic perspective how climate change will harm the [Plaintiffs] if Defendants continue to pursue policies that perpetuate a fossil-fuel-based energy system."[9] Professor Stiglitz claims that "moving the U.S. economy away from fossil fuels is both feasible and beneficial, especially over the next 30 years." He suggests that the U.S. could "facilitate this transition with standard economic tools for dealing with externalities, for example a tax or levy on carbon (a price on the externality) and the elimination of subsidies on fossil-fuel production."

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[4] Complaint, ¶280. See also Complaint, ¶110 ("DOI, through the Bureau of Land Management ('BLM'), leases minerals and manages oil and gas development activities on over 570 million acres of federal lands, as well as on private lands where the federal government retained mineral rights."); Complaint, ¶117 ("USDA, through the U.S. Forest Service, authorizes 25% of U.S. coal production."); Complaint, ¶164 ("In 2013, 25% of all fossil fuels extracted in the U.S. originated on federal public lands."); Complaint, ¶172 ("The United States subsidizes the fossil fuel industry by undervaluing royalty rates for federal public leasing, as well as through royalty relief resulting in the loss of billions of dollars of foregone revenue."); Complaint, ¶173 ("Through eleven federal fossil fuel production tax provisions, the United States incurs approximately $4.7 billion in annual revenue costs."); Complaint, ¶174 ("The United States provides approximately $5.1 billion per year in tax provision subsidies to support fossil-fuel exploration."); Complaint, ¶186 ("All U.S. petroleum refineries are permitted and regulated by EPA."); Complaint, ¶190 ("the United States subsidized the purchase, and thus increased demand for, vehicles weighing more than 6,000 pounds ('SUVs').").
[5] Complaint, ¶¶153.
[6] Complaint, ¶121 ("DOD is our nation's largest employer and is responsible for significant carbon pollution from both its vehicle fleet, and its 500 bases of military infrastructure, including 300,000 buildings totaling 2.2 billion square feet.").
[7] Complaint, ¶¶8, 286, 303–305.
[8] Complaint, ¶¶1–5, 286, 303–305.
[9] Expert Report of Joseph E. Stiglitz, Ph.D., April 13, 2018 ("Stiglitz Report"), ¶18.

He also recommends "revising current government discounting practices." Professor Stiglitz suggests that costs for some actions to address climate change could be negative.[10]

17. Plaintiffs have also submitted expert reports from Professor Mark Z. Jacobson and Professor James H. Williams as evidence that the U.S. can decarbonize its economy.[11]

18. Professor Jacobson concludes that by 2050 the U.S. can completely eliminate the use of fossil fuels and reduce carbon emissions to zero by shifting to a proposed energy system based on (i) electricity generated solely from wind, water, solar power ("WWS power"); (ii) advanced technologies for the storage of electric and solar energy; and (iii) hydrogen-based energy.[12] Professor Jacobson further asserts that barriers to the adoption of such a system "are neither technical nor economic," and that the unit cost of electricity under his proposed system would be lower than under the current generation infrastructure.[13]

19. Professor Williams concludes that "it is technically feasible to develop and implement a plan to achieve an 80% greenhouse gas reduction below 1990 levels by 2050 in the United States,"[14] and that a reduction of 96% relative to current levels "is technologically feasible given current and emerging technologies," but "will likely have a higher unit cost" to go beyond the 80% reduction.[15] He forecasts that the 80% reduction from 1990 levels will cost between -0.2% and +1.8% of 2050 GDP.[16]

20. I have been asked by counsel for Defendants in this matter to address Plaintiffs' assertions regarding U.S. energy policy, assess the theory of harm articulated by Plaintiffs, and evaluate the energy systems proposed by Professor Jacobson and Professor Williams, and to address what would be some implications of granting Plaintiffs' demands.

21. I am being compensated for my work on this matter at my standard billing rate of $800 per hour. Cornerstone Research has assisted me in the preparation of this report; their staff have

[10] Stiglitz Report, ¶19.
[11] Expert Report of Mark Jacobson, Ph.D., April 6, 2018 ("Jacobson Report"); Expert Report of James H. Williams, Ph.D., April 13, 2018 ("Williams Report"). Note that Professor Jacobson also submitted an earlier report in July 2017.
[12] Jacobson Report, p. 2.
[13] Jacobson Report, pp. 4, 11.
[14] Williams Report, p. 3.
[15] Williams Report, p. 12.
[16] Williams Report, p. 3.

worked under my direction. I receive compensation from Cornerstone Research based on its collected staff billings for its support of me in this matter. Neither my compensation in this matter nor my compensation from Cornerstone Research is in any way contingent or based on the content of my opinion or the outcome of this or any other matter. A list of documents that I have relied upon in forming my opinions can be found as Appendix C.

III. Summary of Opinions

22. I offer the Court data, observations, perspectives, and opinions that address certain energy/environmental policy points of Plaintiffs' assertions in this case.

23. By way of background, I firmly believe that global climate change resulting from GHG emissions is real.[17] As I have acknowledged in my publications, a large body of scientific evidence has established that global temperatures are rising and will continue to rise in the future; that increasing atmospheric concentrations of GHGs, including but not limited to CO_2, are the primary cause of rising global temperatures; and that human activity is the primary cause of rising GHG levels.

24. Climate change is a global problem. Data from the U.S. Energy Information Administration ("EIA") shows that the U.S. today accounts for roughly 16% of global energy related CO_2 emissions[18]—hence, unilateral U.S. action cannot possibly stabilize atmospheric CO_2 concentration levels, much less reduce concentrations to the level that Plaintiffs demand. I discuss this in greater detail in Section IV.

25. U.S. energy policy and environmental policy must balance three fundamental objectives that often conflict: national security, economic welfare, and environmental welfare. Each of these fundamental objectives includes multiple components. Plaintiffs, however, adopt a one-dimensional view of energy policy in which policy is evaluated solely through the lens of a subset of concerns relating to environmental welfare—climate change and GHG emissions—and

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[17] I understand that Defendants have stipulated the existence of climate change, that climate change is anthropogenic, and that these questions are not at issue in this litigation. Federal Defendants' Answer to First Amended Complaint for Declaratory and Injunctive Relief, *Kelsey Cascadia Rose Juliana et al., Plaintiffs, v. United States et al., Defendants*, January 13, 2017 ("Answer"), ¶1.

[18] U.S. Energy Information Administration, International Energy Statistics.

not as trade-offs between concerns of national security, economic welfare, and environmental welfare. I discuss this in greater detail in Section V.

26. The U.S. economy has decarbonized dramatically since 1973, and federal programs and policies have contributed substantially to decarbonization, notwithstanding Plaintiffs' allegations that the federal governmental has ignored scientific advice and has done little or nothing to reduce GHG emissions. The energy-related carbon intensity of the U.S. economy—the energy-related CO_2 released per dollar of real (inflation-adjusted) GDP—has decreased by 66% since the energy crisis in 1973. However, the U.S. economy has continued to grow, at different rates over time. The combination of time-varying economic growth, with a simultaneous time-varying decarbonization of the economy, has led to some decades in which CO_2 emissions grew and other decades in which emissions declined. I discuss this in greater detail in Section VI.

27. The reduction in the energy-related carbon intensity of the U.S. economy is due in large part to a broad portfolio of federal governmental policies. These policies, which I discuss in Section VII, include energy efficiency appliance standards, fuel efficiency standards for cars and trucks, research and development ("R&D") sponsorship, tax incentives for energy efficient buildings and technologies, support for zero-carbon energy sources such as hydropower, solar, and wind, and participation in international agreements to mitigate GHG emissions and the impact of climate change.

28. Many policy options suggested in the Complaint and by Plaintiffs' experts have been implemented, including initiatives proposed in the 1990 Environmental Protection Agency study. Others, such as a carbon tax, have been considered, debated, and rejected by Congress or the executive of the federal government. These policy outcomes are examples of the political branches of the federal government balancing the considerations of energy policy—either other factors such as economic welfare or national security have received greater weight than environmental objectives, or federal policy makers have favored other policy instruments, such as direct regulation of energy efficiency. I discuss this in greater detail in Sections VIII and IX.

29. There is an important economic distinction between the direct emissions of the federal government and the federal government's role in regulating the emissions of third parties such as companies, individuals, and state and local governments. The federal government directly

controls its own emissions, but does not control the conduct of third parties. The vast majority of GHG emissions in the U.S. come from the activities of private sector firms, individual residents of the U.S., and state and local governments. Thus, the federal government must rely on either command-and-control mandates or a system of regulations that create incentives to induce third parties to engage in the conduct it desires. Before instituting incentives to encourage or discourage conduct, it is important to consider the costs and benefits of the intervention. I discuss this in Section X.

30. Turning to Plaintiffs' theory of harm, I conclude that Plaintiffs fail to establish a causal link from the conduct at issue to the injuries they allege. Plaintiffs attribute their injuries to the conduct at issue, but ignore the fact that at least 96% of cumulative global CO_2 emissions since 1990—the root cause of rising atmospheric CO_2 concentrations and climate change effects that purportedly lead to Plaintiffs' alleged injuries—are associated with fossil fuel consumption unrelated to the conduct at issue.[19] In particular, I conclude that

a. countries other than the United States accounted for 79% of energy-related CO_2 emissions from 1990 to 2015;

b. a large majority of the remaining 21% of energy-related CO_2 emissions during this period were not caused by the conduct at issue;

c. CO_2 emissions caused directly by the government through its consumption of fossil fuels comprise approximately 0.25% of global CO_2 emissions; and

d. I estimate that CO_2 emissions caused by all of the conduct at issue, including emissions allegedly caused directly by Defendants, emissions allegedly caused by Defendants' affirmative policy acts, and emissions allegedly caused by Defendants' alleged failure to act, comprise no more than 4% of global emissions. Note that this figure includes emissions from the actions of entities in the U.S. other than the federal government, including private sector firms, individual residents of the U.S., and state and local governments.

[19] For purposes of rebuttal, I assume *arguendo* that the conduct at issue began as of 1990.

31. Further, I conclude that Plaintiffs fail to establish a causal link between their alleged injuries and climate change effects allegedly caused *by the conduct at issue*. Factors other than the conduct at issue are the primary causes of the climate change effects that the Plaintiffs allege to have caused injuries. I discuss this in greater detail in Section XI.

32. Finally, the low-carbon energy systems proposed by Plaintiffs' experts, Professor Jacobson and Professor Williams, are not technically feasible, and assume the existence of technologies that are in development and are decades from commercial acceptance. Neither Professor Jacobson nor Professor Williams provides a credible estimate of the full costs of their respective proposals. They both focus on changes in the cost of energy supply, but fail to explain the substantially larger costs that would arise from the macroeconomic impact of their respective proposals. Moreover, Professor Jacobson's prominent claim that his proposed system would provide electricity at prices lower than a conventional system relies on aggressive, implausible assumptions. Their proposed energy systems would also require a very high level of regulatory intervention in the economy, as Professor Williams himself concedes. Professor Jacobson simply dismisses this consequence as a "social or "political" barrier to implementation. Additionally, Professor Jacobson's and Professor Williams' proposals deviate from consensus views in the literature. Addressing global climate change is an important objective, but it must be pursued realistically within the institutional framework of our economic and political system. Plaintiffs' experts have not demonstrated that their approaches are realistic or likely to succeed in practice. I discuss these conclusions in Section XII.

IV. Climate Change Is a Real, Global Problem

A. Global Climate Change Resulting from Greenhouse Gas Emissions

33. I understand that the impact of fossil fuel emissions on the climate is not in dispute in this case.[20] As I have acknowledged in my publications,[21] a large body of scientific evidence has

[20] Answer, ¶1.

[21] James L. Sweeney, *Energy Efficiency: Building a Clean, Secure Economy* (Stanford, CA: Hoover Institution Press, 2016) ("Sweeney"), pp. 1–196 at p. 85. See also Kenneth Gillingham and James Sweeney, "Market Failure and the Structure of Externalities," in *Harnessing Renewable Energy*, ed. Boaz Moselle et al. (New York: Routledge, 2010), pp. 1–23 at p. 73; Arthur van Benthem et al., "Learning-by-Doing and the Optimal Solar Policy in California," *Energy Journal* 29, no. 3, 2008, pp. 1–26 at p. 2.

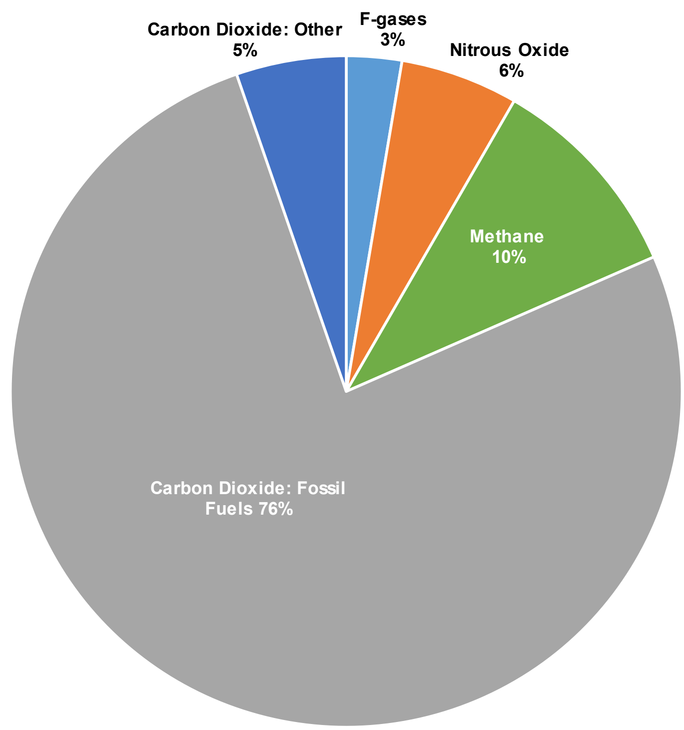
established that global temperatures are rising and will continue to rise in the future; that increasing atmospheric concentrations of GHG, including but not limited to CO_2, are the primary cause of rising global temperatures; and that human activity is the primary cause of rising GHG levels.

34. According to the Intergovernmental Panel on Climate Change ("IPCC")'s fifth assessment report, "for most economic sectors, the impacts of drivers such as changes in population, age structure, income, technology, relative prices, lifestyle, regulation, and governance are projected to be large relative to the impacts of climate change… Global economic impacts from climate change are difficult to estimate… there are large differences between and within countries."[22] The negative impacts and the difficulties of adapting will be felt primarily by developing countries and low-lying island nations. Developed countries such as the U.S. will have the technical knowledge, information, skills, infrastructure, and institutions to allow adaptation to the changing conditions, whereas many developing countries have less capacity to adapt and are therefore more vulnerable.

[22] See, for example, IPCC Report, "Climate Change 2014 Impacts, Adaptation, and Vulnerability Summary for Policymakers," 2014, p. 19.

35. I understand that it is undisputed in this lawsuit that GHG emissions result from the combustion of fossil fuels.[23] In the U.S., in 2016 about 76% of GHG emissions were CO_2 from combustion of fossil fuels. Another 5% were CO_2 from forestry and other land use. About 10% were methane. This distribution of U.S. greenhouse gases is depicted in Figure 1. Thus, the elimination of only CO_2 emissions from fossil fuel combustion would not eliminate all greenhouse gases.

Figure 1. U.S. Greenhouse Gas Emissions by Gas



Source: U.S. Environmental Protection Agency, 2018, "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016," Table ES-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (MMT CO_2 Eq.)

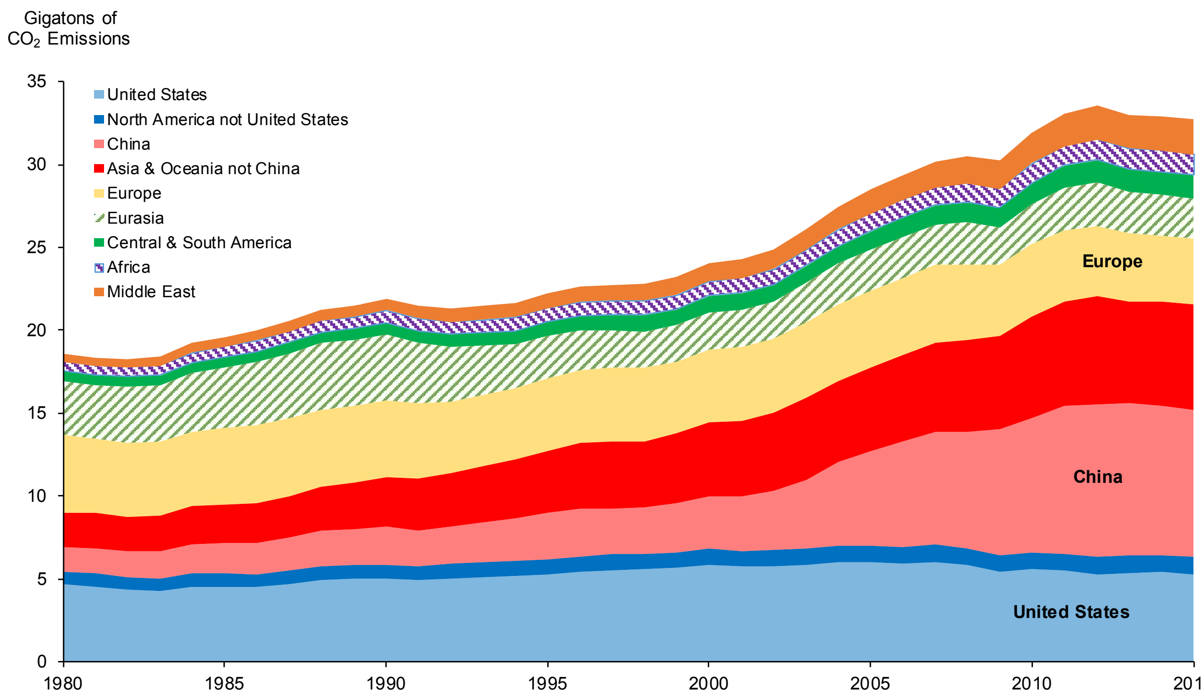
[23]Answer, ¶1.

B. The U.S. Alone Cannot Ensure That Atmospheric CO_2 Is No More Concentrated than 350 ppm by 2100

36. Plaintiffs demand that the federal government should be ordered to assure that the climate system is stabilized at no more than 350 ppm CO_2 by 2100.[24] But climate change is a global problem. Unilateral U.S. action, whether it eliminates direct federal government emissions or could somehow eliminate private sector and state/local government emissions, cannot stabilize atmospheric CO_2 concentration levels, much less reduce CO_2 concentrations to the level requested by Plaintiffs.

Figure 2. Annual CO_2 Emissions from Energy

1980–2015



Source: U.S. Energy Information Administration, International Energy Statistics

[24] Complaint, ¶12.

37. Although the U.S. has historically contributed about 25% of global CO_2 emissions,[25] it now emits only a small fraction of global GHG emissions. The recent data, graphed in Figure 2, show that the U.S. contributed 16% of the global energy emissions of CO_2 from fossil fuels as of 2015.[26] Most of these emissions (84%) came from other countries. The largest emitter, China, contributed 27% of the world emissions from fossil fuels. In the U.S. there has been little growth over the last 35 years in CO_2 emissions from the energy system. In Europe there has been a decline. The largest growth has been in China and in the rest of Asia and Oceania.

38. Therefore, unilateral U.S. action cannot halt global emissions or stabilize the level of atmospheric CO_2 concentration. Even if the U.S. were to unilaterally eliminate all use and production of fossil fuels tomorrow, worldwide energy related CO_2 emissions would be at least 84% of current emissions and would continue to grow, as would CO_2 concentration. And 84% is likely to be a lower estimate. If the U.S. halted its use and production of fossil fuels, the prices of these fuels would fall and other counties would increase their use of fossil fuels, thereby partially offsetting the U.S. reduction in emissions.[27] As a result, unilateral action by the U.S. could not provide Plaintiffs with the relief that they seek—that is, CO_2 concentration no greater than 350 ppm. Any solution to climate change requires global coordination and cannot be based on U.S. action alone.

39. Recent IPCC research concludes that achieving atmospheric CO_2 concentrations below 430 ppm—not 350 ppm—by 2100 would require a reduction of 70% to 95% in *global* GHG emissions relative to 2010 levels.[28] The IPCC assessment involves a large number of scenarios published in the scientific literature.[29] The U.S. GHG emissions, accounting for just 16% of global CO_2 energy related emissions, is well short of the 70% reduction the IPCC deemed necessary. Thus, even if the U.S. completely eliminated CO_2 emissions from energy immediately, the reduction in global CO_2 emissions would not be sufficient to stabilize CO_2

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[25] Answer, ¶151.
[26] U.S. Energy Information Administration, International Energy Statistics.
[27] The U.S. is a net importer of fossil fuels, so halting all use and production of fossil fuels would decrease world demand more than it would world supply of fossil fuels. See U.S. Energy Information Administration, "July 2018 Monthly Energy Review," Table 1.4b Primary Energy Exports by Source and Total Net Imports.
[28] IPCC Report, "Climate Change 2014 Synthesis Report Summary for Policymakers," 2014, p. 21.
[29] IPCC Report, "Climate Change 2014 Synthesis Report Summary for Policymakers," 2014, p. 22.

concentrations below 430 ppm by 2100, much less reach the 350 ppm concentration that Plaintiffs seek.

40. Even global coordination may not be sufficient to yield the relief that Plaintiffs demand. The Emissions Gap Report 2017 by the United Nations Environment Programme ("UNEP") states that "[a] large gap exists between 2030 emission levels and those consistent with least-cost pathways to the 2 degrees C and 1.5 degrees C goals respectively,"[30] and that "the assessment shows that for many countries, implementing their Nationally Determined Contribution ('NDC') would lead to lower emissions than the current policies scenario, or in other words that additional policies will have to be implemented to meet the NDC target."[31] This indicates that not only is there a "gap" between current pledges and the progress required to meet temperature goals, but there is also a "gap" between what countries' current policies are and what they would need to be to achieve those pledges.

41. Though climate change is a global problem, Plaintiffs focus on the U.S. government's policies regarding climate change. I discuss the framework in which U.S. energy policy is created in the next section.

V. Energy Policy in the U.S. Requires Trade-Offs among Economic, Security, and Environmental Objectives

42. U.S. energy policy is the outcome of a policymaking process that balances at least three competing fundamental objectives: economic growth/welfare, domestic and international security, and environmental objectives, referred to as the "Energy Policy Triangle."[32] The Energy Policy Triangle describes the trade-offs between the competing objectives, and has been the framework (implicitly or

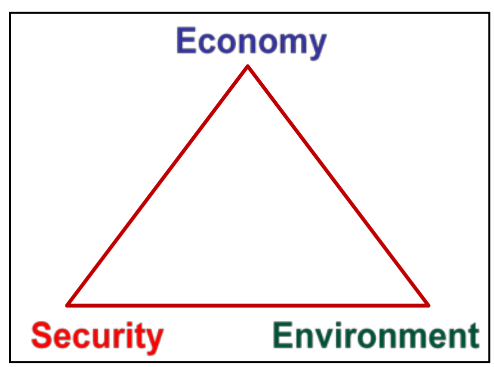

Figure 3. The Energy Policy Triangle

[30] UNEP Report, "The Emissions Gap Report 2017," 2017, p. xvii.
[31] UNEP Report, "The Emissions Gap Report 2017," 2017, p. xviii ("Most G20 countries require new policies and actions to achieve their NDC pledges.").
[32] Sweeney, pp. xv, 166.

explicitly) of energy policy discussions since at least 1973.[33] These goals have been adopted not just by the U.S. but internationally, although different countries place different emphases on the three goals.[34] Likewise, different U.S. administrations have placed different emphases on the three goals.

A. The Environment

43. Energy-related issues of the environment include local and international impacts of energy production and use. Environmental outcomes are influenced by the economic and policy processes that influence the mix of primary energy sources,[35] the energy conversion processes (e.g., in the generation of electricity), and the amounts and types of energy that are consumed. In the U.S., economic and policy processes that have led to growing energy efficiency have been good for the environment: reductions in energy use mean that less energy needs to be produced, transported, or transmitted. Less energy use implies less GHG emissions in the atmosphere.[36]

44. Other domestic environmental impacts include release of particulates, oxides of nitrogen, sulfur dioxide, and other pollutants into the air; water pollution associated with the production of fossil fuels such as coal or natural gas; use of water for production of primary energy or for conversion of primary energy into electricity; and disruption of natural habitats. Energy policy

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[33] Sweeney, p. xv; Raphael J. Heffron, "What is Energy Law," in *Energy Law: An Introduction* (Springer International Publishing, 2015), pp. 1–10 at pp. 3–4. An early example of the tension in energy policy between economic and national security interests can be seen in the Eisenhower administration's decision to prohibit the export of crude oil on national security grounds. See Deon Daugherty, "Limit Crude Imports: Perhaps Eisenhower Was on to Something," *Rigzone*, January 25, 2016, https://www.rigzone.com/news/oil_gas/a/142660/column_limit_crude_imports_perhaps_eisenhower_was_on_to_something/?all=hg2, accessed August 3, 2018.

[34] The U.S. is not unique in its efforts to balance competing objectives in its energy policy. Other countries also conduct the same balancing exercise when setting energy policy. The World Energy Council has used the term "Energy Trilemma," for three (sometimes competing) aspects of energy policy: energy security, energy equity (accessibility and affordability of energy), and environmental sustainability. World Energy Council Report, "World Energy Trilemma 2016," 2016, p. 12. In an annual report published since 2010, the World Energy Council assesses countries' energy policy in the "trilemma lens" since "neglecting one dimension of the trilemma can result in unintended consequences and higher future costs in economic, social and environmental terms." World Energy Council, "World Energy Trilemma 2016," 2016, pp. 10, 25. Another example of using the term energy trilemma is Australia. See, for example, David Byrne, "Australia's Energy Trilemma Explained," *The University of Melbourne*, July 3, 2017, https://pursuit.unimelb.edu.au/articles/australia-s-energy-trilemma-explained, accessed August 6, 2018.

[35] "Energy commodities are either extracted or captured directly from natural resources (and are termed primary) such as crude oil, hard coal, natural gas, or are produced from primary commodities. All energy commodities which are not primary but produced from primary commodities are termed secondary commodities. Secondary energy comes from the transformation of primary or secondary energy." See International Energy Agency, *Energy Statistics Manual* (Paris: IEA Publications, 2005), p. 18.

[36] Sweeney, p. 4.

that has set standards on new and existing sources of these pollutants have had environmental benefits.[37]

B. Domestic and International Security

45. Issues of security include the vulnerability of the U.S. and its allies to military and terrorist attacks. This important issue has led to the need for strong military and governmental policies and programs to maintain a strong defense. Military ships, airplanes, motor vehicles, and land bases use energy of various types, including oil and natural gas. In addition, an important security issue is the vulnerability of the U.S. to deliberate or accidental restrictions on oil imports, vulnerability of the U.S. economy to rapid fluctuations in energy prices, or limitations placed on U.S. foreign-policy options as a result of U.S. dependence on foreign energy sources.[38]

46. Increases in domestic production of energy have been important in enhancing domestic and international security.[39] Adequate domestic supplies of oil have assured that the U.S. military is not dependent on foreign sources of oil, particularly from unstable parts of the world, such as the Middle East. Energy efficiency in the military, likewise, has reduced the military dependency on fossil fuels.[40]

47. For at least 60 years, the U.S. has been a net importer of energy, particularly oil.[41] Subsequent to the energy crisis of 1973–1974, public and private sector actions to increase domestic production of energy, including oil and natural gas, have been important in reducing net energy imports. Likewise, energy efficiency has allowed the U.S. to reduce energy imports. The combination of energy efficiency and increased domestic energy production have together

[37] Sweeney, p. 4, fn. 4.
[38] Sweeney, p. 4.
[39] Jason Furman and Gene Sperling, "Reducing America's Dependence on Foreign Oil As a Strategy to Increase Economic Growth and Reduce Economic Vulnerability," August 29, 2013, *Obama White House Archives*, available at https://obamawhitehouse.archives.gov/blog/2013/08/29/reducing-america-s-dependence-foreign-oil-strategy-increase-economic-growth-and-redu, accessed August 2, 2016 ("The increased domestic supply combined with increased oil efficiency of the economy reduces vulnerability to global supply disruptions and price shocks, enhancing our national security.").
[40] Sweeney, p. 107. See also The Pew Charitable Trusts Report, "Power Surge: Energy Security and the Department of Defense," January 2014, p. 1 ("The research in this report details how defense leaders have initiated wide-ranging steps to harness advanced technologies to conserve energy, enable on-site production from renewable sources, and save taxpayers millions of dollars.").
[41] Sweeney, p. 95, Figure 3.11. See also U.S. Energy Information Administration, "May 2018 Monthly Energy Review," Table 1.4b Primary Energy Exports by Source and Total Net Imports.

reduced energy imports enough that the U.S. may soon become self-sufficient in energy, thereby increasing security.[42]

C. The Economy

48. Economic issues include growth of GDP, the number and quality of jobs available for the population, and the distribution of wealth and income. Energy has been a fundamental input to almost all economic activity. Economic growth, absent changes in energy efficiency, leads to roughly proportional increases in the use of all forms of energy.[43] Reducing the energy use per unit of economic activity of productive inputs works in the opposite direction, reducing energy use. Energy use is influenced by the policy trade-offs between economic growth and energy efficiency. With additional economic growth, the U.S. population enjoys increases in personal income. That income is spent on homes, transportation, entertainment, and consumption of goods, all of which increase use of energy.

49. Domestic production of energy, including fossil fuels, provides profits to firms and employment of a labor force. U.S. economic policy has been to provide jobs.[44] Domestic production of energy, particularly in U.S. regions dependent on fossil fuels, has been a policy objective for the U.S. derived from the U.S. policy to create jobs and profitable industries. It is a matter of debate whether production of wind and solar energy would similarly fulfill the employment policy objective in each area of the country currently dependent on the production of fossil fuels.[45]

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[42] Sweeney, p. 167.

[43] See Shaojian Wang et al., "The Relationship Between Economic Growth, Energy Consumption, and CO2 Emissions: Empirical Evidence from China," *Science of The Total Environment* 542, 2016, pp. 360–371 ("Causal relationships were found to exist between economic growth, energy consumption, and CO_2 emissions; specifically, a bi-directional causal relationship between economic growth and every consumption was identified.").

[44] Congress has established the United States Federal Reserve's three primary objectives: maximum employment, stable prices, and moderate long-term interest rates. See "What are the Federal Reserve's objectives in conducting monetary policy?" *Federal Reserve*, June 13, 2018, https://www.federalreserve.gov/faqs/money_12848.htm, accessed August 3, 2018.

[45] One example of this debate are the academic discussions related to Professor Jacobson's work. A review of one of Professor Jacobson's proposals finds that "replacing fossil fuels with renewable technologies like wind and solar would actually cause a new loss of 1.2 million long-term jobs." See Steve Everley, "Stanford's Jacobson Spins Energy Misinformation (100% renewables fantasy)," *MasterResource*, 2016, https://www.masterresource.org/renewable-energy-and-jobs/stanfords-jacobson-spins-misinformation-in-the-energy-debate-100-renewables-fantasy/, accessed August 3, 2018.

50. Energy efficiency has been a U.S. policy that helps the economy while reducing the use of energy, for a given level of economic activity. Reductions in the government use of energy have provided savings for the federal government, reduced the federal deficit, and reduced the balance of the trade deficit.[46] Cost-effective reductions in the use of energy by businesses can make them more profitable and thus increase GDP. Cost-effective reductions in the use of energy by households can leave more disposable income available for other purposes. Particularly for low-income households, reductions in energy costs can be important for overall well-being. Reduced use of electricity has avoided the need to construct thousands of megawatts of new electric generation stations, saving billions of dollars.[47]

D. Energy Policy Involves Trade-Offs among the Three Goals

51. As described above, environmental protection, although an important goal, is not the only consideration in setting national energy policies. The U.S. has attempted to balance the three competing fundamental objectives: economic growth/welfare, domestic and international security, and environmental objectives. Some actions, such as energy efficiency, could be supportive of all three objectives. Other actions, such as encouraging domestic production of natural gas, could be supportive of all three in the short run—for example, by substituting for coal and thus decreasing CO_2 emissions—while harmful for environmental objectives in the long run. Other actions, such as encouraging domestic production of oil, can be valuable for national security and for economic objectives, even though they may be harmful for environmental goals.

52. Energy and energy/environmental policy in the U.S., at least since the energy crisis of 1973–1974, requires trade-offs among these various fundamental objectives. In the U.S., Congress and the federal administrations have debated these trade-offs and have made regulatory decisions that explicitly took these trade-offs into account.[48] For example, as discussed below, automotive fuel economy standards have reduced GHG emissions, increased energy security, but have led to higher economic costs for consumers.

[46] Sweeney, p. 5.
[47] Sweeney, p. 5.
[48] Examples of energy policies and their trade-offs are discussed in Sections VII-IX.

53. There has not been consistent agreement over time among the general U.S. population or Congress about the relative weights that should be given to the various objectives of energy policy. For example, in the decades after the oil crisis of 1973–1974, a great weight was given to national security. Over time, the weight given to the environmental objective has appeared to grow. In addition, there has always been a heavy weight on the economic growth objective, but the weight given to the economic well-being of various regions of the country appears to change over time.

54. Moreover, there has not been consistent agreement among people or between political parties about the relative weights that should be given to the various objectives. Differences among U.S. citizens has played out in Congress and within federal administrations, with some elected representatives placing more weight on economic growth, others placing more weight on environmental protection, and still others placing more weight on national security. Even within a given category, there are differences. For example, many concerned about the environment could put more weight on protection of local land use while others may be more concerned with global climate change. Within the economic objective, some could put more weight on economic welfare of particular disadvantaged regions and others more weight on the overall rate of economic growth.

55. Given the differences in the relative weights placed on the various objectives—differences across people and over time—some of the trade-offs have favored the environmental objective, others the national security objective, and still others the economic objective. Indeed, some trade-offs have benefited all three objectives. For me this is not surprising in a democratic society.

56. In contrast, Plaintiffs adopt a narrow, one-dimensional view of energy policy, and appear to imply that U.S. policy should singularly focus on reducing the production and use of fossil fuels. They appear to allege that the U.S. Constitution requires the government to determine energy policy solely on the basis of its environmental effects, and in particular its effect on GHG emissions.[49] Plaintiffs allege that the U.S. Constitution should not allow government policies that permit, subsidize, and create incentives for the production and consumption of fossil fuels,

[49] Complaint, ¶¶8, 286, 303–305.

and criticize the U.S. government's alleged failure to develop policies that reduce fossil fuel production and consumption.[50] They do not acknowledge the other objectives of energy policy—that is, national/international security and economic growth/health—nor do they seem to recognize that some of the policies they criticize have supported these other two objectives. Plaintiffs also overlook that some U.S. policies have been very supportive of environmental goals.

57. An early example illustrates the federal government's recognition that energy policy involves complex trade-offs and should not be a narrow, one-dimensional focus on one single objective.

58. In 1973, during the energy crisis resulting from the oil embargo, the Nixon administration announced Project Independence, an energy policy balancing economic and national security concerns with a goal of achieving U.S. energy self-sufficiency by 1980.[51] The *Project Independence Report*, published by the U.S. Federal Energy Administration in 1974, made it clear that U.S. energy policy, while addressing issues of national security, must take into account various impacts on the economy and the environment. The report stated:[52]

> "The embargo made obvious the need to reevaluate our domestic and international energy policies and to fashion a new energy program to hold our vulnerability to acceptable levels.
>
> …
>
> "Unfortunately, the reduction of imports, if it means the substitution of more expensive domestic energy sources, could very easily be accompanied by much higher domestic energy prices, inflation, a drop in real gross national product (GNP), supply risks, and a number of other undesirable effects, such as environmental degradation and depletion of reserves.
>
> …
>
> "Any policy which reduces our dependence on imports and economic vulnerability to supply disruptions will have other effects that must be considered. These are discussed below.
>
> <u>The Domestic Economic Impact of the Strategy.</u> The overall economic impact of an energy strategy can be measured through the standard indicators -- real growth in the

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[50] Complaint, ¶¶99, 106.

[51] Richard Nixon, "Address to the Nation About Policies To Deal With the Energy Shortages," *The American Presidency Project*, November 7, 1973, http://www.presidency.ucsb.edu/ws/?pid=4034, accessed August 3, 2018.

[52] Federal Energy Administration, "Project Independence," Project Independence Report, November 1974, pp. 18–20, https://catalog.hathitrust.org/Record/000686195.

GNP, the rate of inflation, and the unemployment rate. The effect on the balance of payments, and any extraordinary impact concentrated on particular localities, economic sectors or income groups, must also be measured.

The Environmental Impact of the Strategy. The quality of life is measured in more than economic terms, and environmental quality is a key element of such an assessment. In addition to air and water pollution, the impact on land use and recreation for each energy strategy must also be measured. This is usually a very difficult evaluation to perform, because the trade-offs are incommensurate. How, for instance, should one value the preservation of a remote, pristine Alaska wilderness area versus the development of offshore oil near major recreational areas on the north east coast?

The Degree of Federal Intervention Required to Implement the Strategy. An otherwise acceptable strategy might involve an intolerable or unfeasible amount of Federal intervention. Under this criterion are included financial intervention in the form of taxes or subsidies, and new energy- related regulations. The analysis must also include institutional intervention into environmental, health and safety matters, and licensing and regulatory barriers.

The Effect of the Strategy on World Oil Prices. If domestic strategies can significantly affect U.S. imports, then such strategies may also affect the world supply/demand balance. Hence, they must be weighed in terms of their international ramifications and, consequently, their impact on U. S. import price expectations."

59. In recognition of the complexity of energy policy, the *Project Independence Report* identified four broad strategic alternatives for U.S. national energy policies to achieve U.S. energy self-sufficiency, recognizing that "practically speaking, any final Project Independence program would almost surely be a mixed strategy taking elements from each."[53]

"A Base Case, in which existing policies continue and only limited new actions are considered.

An Accelerated Supply Strategy, in which the Federal Government takes a number of key actions to increase the domestic supply of energy ….,

A Conservation Strategy, which would reduce demand for petroleum …. ,

An Emergency Preparedness Strategy …."

60. These broad strategic alternatives reflected the explicit understanding that any individual alternative would have impacts on the environment, the economy, and on national security.

[53] Federal Energy Administration, "Project Independence," Project Independence Report, November 1974, p. 20, https://catalog.hathitrust.org/Record/000686195.

61. The Nixon administration, and subsequently the Ford and Carter administrations, created institutions and regulations and signed legislation in pursuit of these strategic alternatives and broad policy goals.[54]

62. In 1977, the Carter administration combined the various energy-related offices, the Federal Power Commission, and other agencies into the DOE.[55] The Congressional Findings in the Department of Energy Organization Act of 1977 make it clear that the DOE would support multiple objectives:[56]

> "The Congress of the United States finds that—
>
> (1) the United States faces an increasing shortage of nonrenewable energy resources;
>
> (2) this energy shortage and our increasing dependence on foreign energy supplies present a serious threat to the national security of the United States and to the health, safety and welfare of its citizens;
>
> (3) a strong national energy program is needed to meet the present and future energy needs of the Nation consistent with overall national economic, environmental and social goals; …"

63. The major initiatives in U.S. energy policy since the creation of these institutions provide many examples of the tension between the elements of the Energy Policy Triangle.

64. I now turn to what has been accomplished within the framework of the Energy Policy Triangle.

VI. The U.S. Economy Has Decarbonized 66% since 1973

65. To analyze the changes in the CO_2 emissions from energy use in the U.S. economy, one can use the Kaya identity, which expresses CO_2 emissions as the product of three factors: the

[54] In 1973 the Nixon administration created several energy-related offices, which subsequently were combined into the Federal Energy Administration in 1974. The Energy Research and Development Administration was created by the Energy Reorganization Act of 1974. Also in 1974 the International Energy Agency was founded as a Paris-based intergovernmental organization under the Organization for Economic Co-operation and Development (OECD). Sweeney, pp. 81, 91, 137.

[55] 42 U.S.C., §§7111, 7151.

[56] 42 U.S.C., §7111.

amount of CO_2 emissions per unit of energy use, the amount of energy use per unit of real GDP, and the real GDP.[57] Mathematically, this identity can be written as follows:

$$CO_2 = GDP \times (CO_2/\text{Energy Use}) \times (\text{Energy Use}/GDP)$$

66. The Kaya identity can also be used to explain changes in the "carbon intensity" of the economy. Carbon intensity is the total CO_2 emission per dollar of real (inflation adjusted) GDP. Dividing each side of the equation above gives carbon intensity of the economy as a product of two factors:

$$CO_2/GDP = (CO_2/\text{Energy Use}) \times (\text{Energy Use}/GDP)$$

67. The first term on the right-hand side of this identity, the CO_2 emissions per unit of energy use, is the carbon intensity of energy consumption. For example, if low carbon or carbon free fuels substituted for fossil fuels and the carbon intensity of energy consumption were reduced by 11%, this identity shows that, with all else equal, the CO_2 emissions per unit of GDP would be likewise cut by 11%.

68. The second term on the right-hand side is the energy use per unit of GDP, the energy intensity of the economy. If the energy intensity of the economy were to decline by 50%, this identity shows that, with all else equal, the carbon intensity of the economy would likewise be cut by 50%. If GDP is not influenced, CO_2 emissions per unit of GDP would be cut by 50%.

69. The decomposition of carbon intensity of the economy into the two components of energy intensity of the economy and carbon intensity of energy consumption helps in separating the historical impacts of energy efficiency from those of changing energy supply technologies.

70. Enhancement of energy efficiency reduces the energy intensity of the economy. Provision of low carbon or carbon-free supplies of energy reduces the carbon intensity of the energy system. Either reduction taken alone reduces the carbon intensity of the economy.

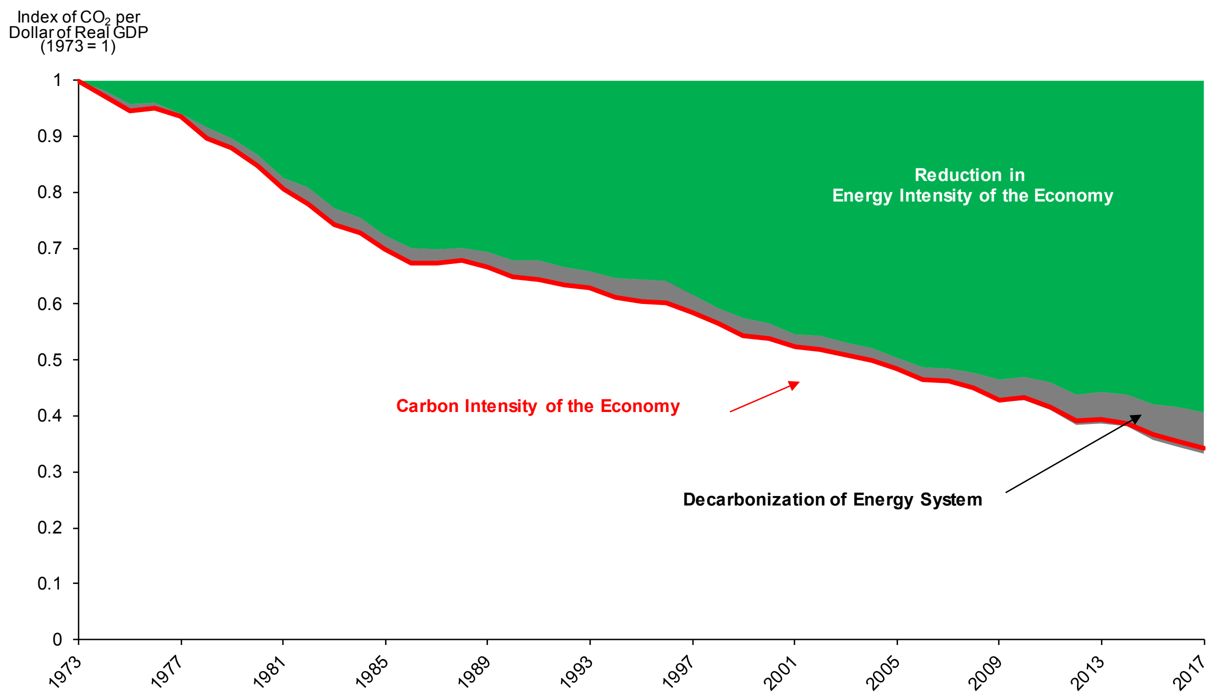
[57] An identity is a mathematical equality that must always be true no matter the value of the variables. The particular identity, the Kaya identity, is named after Yoichi Kaya. See Yoichi Kaya and Keiichi Yokoburi, *Environment, Energy, and Economy: Strategies for Sustainability* (United States of America: United Nations University Press, 1997).

71. For a given GDP growth over time, the lower the carbon intensity of the economy, the lower are carbon emissions. Reductions in carbon intensity have reduced carbon emissions from what they would have been otherwise.

72. GHG emissions have in fact been reduced from what they would otherwise have been, given the economic growth in the U.S. Energy policy has provided research and development, direct actions, regulations, and incentives to decarbonize the economy.

Figure 4. Factors Leading to Reduced Carbon Intensity of U.S. Economy

1973–2017



Source: U.S. Energy Information Administration, "July 2018 Monthly Energy Review," Table 1.7 Primary Energy Consumption, Energy Expenditures, and Carbon Dioxide Emissions Indicators, Table 12.1 Carbon Dioxide Emissions From Energy Consumption by Source; Federal Reserve Bank of St. Louis

73. As a result of the actions of many entities, including the federal government, the U.S. has greatly decarbonized since the energy crisis of 1973–1974. This can be seen in Figure 4. The red line shows the carbon intensity of the U.S. economy from 1973 through 2017, relative to the carbon intensity in 1973. The data are normalized relative to 1973 levels, so the carbon intensity of the economy is shown as 1.0 in 1973. Figure 4 shows that the carbon intensity has declined by 66%: the carbon intensity of the U.S. economy in 2017 was only 34% of its value in 1973.

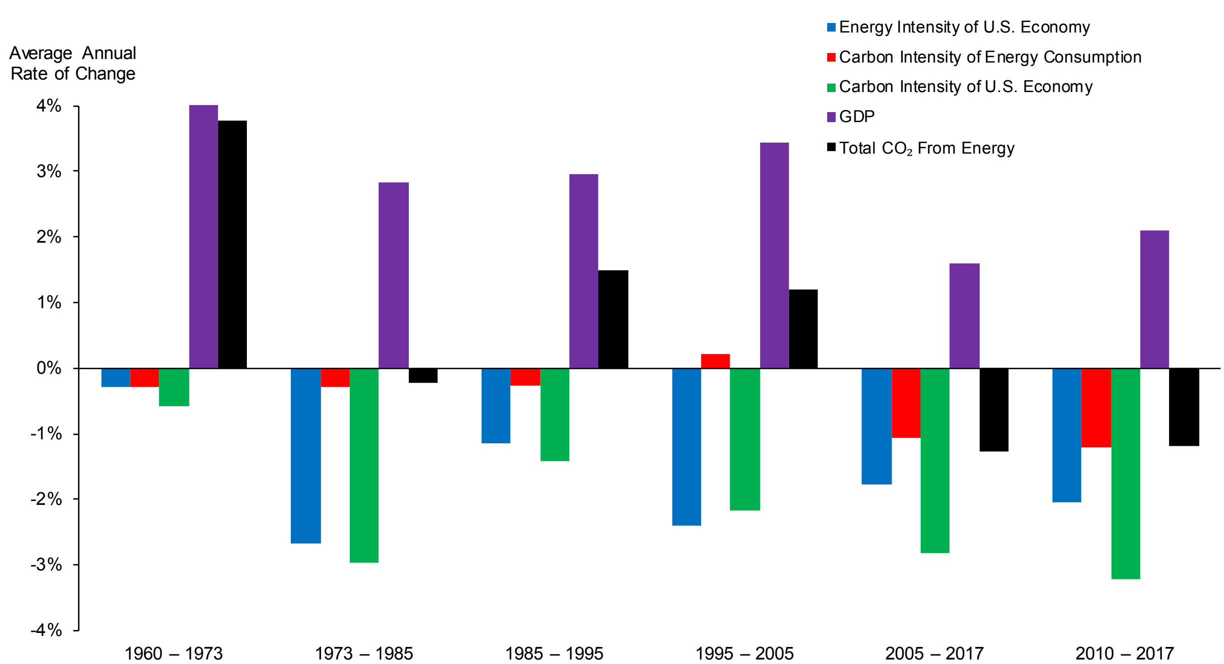
74. Figure 4 also decomposes the reduction in carbon intensity into the two factors in the Kaya identity: the impacts of reduced energy intensity since 1973 (shown in green), and impacts of reduced carbon intensity of energy consumption (shown in grey.) Together, these two factors account for the 66% reduction in the carbon intensity of the U.S. economy.

75. The energy intensity has decreased 59% from its 1973 value: in 2017 the energy intensity of the U.S. economy is only 41% of its value in 1973. The carbon intensity of energy has decreased 16%: U.S. energy consumption in 2017 is 84% as carbon intense as it was in 1973. These two factors are multiplicative, as shown in the Kaya identity, leading to the reductions in 2017 carbon intensity of the U.S. economy to 34% of its value in 1973.

76. Although the carbon intensity of the economy has decreased sharply, CO_2 emissions have increased since 1973 because the economy has continued to grow. This can be illustrated by Figure 5, which shows the various factors in the Kaya identity over time intervals. The data plotted are the average annual rates of change of each variable over the time intervals.

Figure 5. Factors in the Kaya Identity by Time Interval

1960–2017



Source: U.S. Energy Information Administration, "July 2018 Monthly Energy Review," Table 1.7 Primary Energy Consumption, Energy Expenditures, and Carbon Dioxide Emissions Indicators, Table 12.1 Carbon Dioxide Emissions From Energy Consumption by Source; U.S. Energy Information Administration Report, "Annual Energy Review 2011," Table 11.1 Carbon Dioxide Emissions from Energy Consumption by Source, Selected Years, 1949-2011; Federal Reserve Bank of St. Louis

77. In Figure 5, the blue bars represent the annual rate of change of the energy intensity of the U.S. economy; the red bars represent the annual rate of change of the carbon intensity of energy consumption. The size of these two bars add together to give the green bar, the annual rate of change of the carbon intensity of the U.S. economy.[58] The purple bar shows the annual rate of change of the real (inflation-adjusted) GDP of the economy. The green and the purple bar add together to show the annual rate of change of CO_2 emissions from the use of energy in the U.S., represented by the black bars.

78. Figure 5 shows that prior to the 1973–1974 energy crisis, the energy intensity of the economy had been declining by only 0.3% per year and the carbon intensity of the economy had been declining by only 0.6% per year. With the GDP increasing by 4.4% per year, CO_2 emissions from energy use increased by 3.8% per year, on average.

79. However, in the years after the crisis, the energy intensity of the economy started decreasing much more rapidly. In the 12 years immediately after the energy crisis—a time of high energy prices and considerable energy efficiency policy—energy intensity decreased on average by 2.7% per year. Subsequent intervals showed energy intensity falling by between 1.1% and 2.4% per year. Carbon intensity of the economy decreased by 3.0% annually in the 12 years immediately after the energy crisis and in subsequent 10–year or 12–year intervals by between 1.4% and 2.8% annually.

80. An important policy goal for the U.S. economy, however, has been economic growth. In each time period considered, real GDP grew on average between 1.6% and 4.4% annually. This rate of economic growth was greater than the decline of carbon intensity in all but two of the decades. Specifically, CO_2 emissions from the energy sector increased in all but the 12 years immediately following the energy crisis and the most recent 11 years.

81. This figure illustrates the policy trade-offs facing the U.S. economy. If the decrease in carbon intensity of the economy had remained at the levels shown in Figure 5, but all economic growth had stopped as of 1973, CO_2 emissions from energy use would have declined by 66% over that time. However, the real GDP in 2017 would be only a third of its actual level. It is

[58] The rates of change add together because the factors are multiplicative.

dubious whether any federal administration, Republican or Democratic, would have considered that as a preferable outcome.

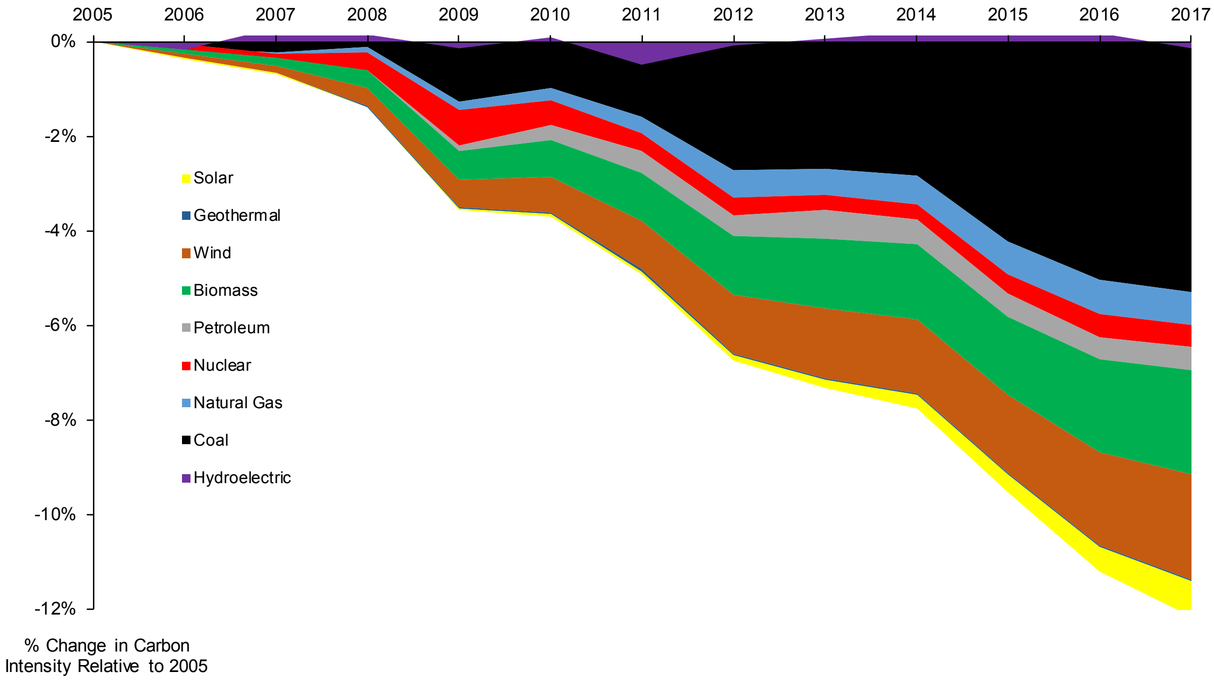
82. Conversely, if the real GDP growth rates had remained at the levels shown in Figure 5, but there had been no reduction in either the carbon intensity of energy use or the energy intensity of the economy, CO_2 emissions from energy use would be roughly three times as large as they are currently. Having worked with political entities over the course of my career, beginning with my time as an Office Director of the Federal Energy Administration (1974 through 1976) I opine that no federal administration, Republican or Democratic, would have considered that as a preferable outcome. And I personally have not and would not advocate such an alternative.

83. In addition, Figure 5 shows that during the time interval from 2005 through 2017, the carbon intensity of the consumed energy decreased by over 1% per year, further decarbonizing the U.S. economy. This trend came about because the fractions of primary energy consumed in the U.S. changed. For primary energy sources with carbon content lower than the weighted average of the primary energy in the U.S. system, *increases* in market shares decrease the carbon intensity of energy consumed. Similarly, for primary energy sources with carbon content greater than the weighted average of the primary energy in the U.S. system, *decreases* in market shares decrease the carbon intensity of energy consumed.

84. Figure 6 shows the impacts of such changing market shares on the carbon intensity of the energy system, from 2005 through 2017. It demonstrates that the greatest impact on carbon intensity of the energy system has been the decrease in market share of coal, primarily because natural gas is substituting for coal in electricity generation. Adding together two impacts—that of decreased market share of coal and that of increased market share of natural gas (which is less carbon intense than the overall U.S. energy system)—shows that this substitution of natural gas in place of coal has decarbonized the economy by 6% over the 11-year period from 2005 through 2017.

Figure 6. Components of Energy System Decarbonization

2005–2017



Source: U.S. Energy Information Administration, "July 2018 Monthly Energy Review," Table 1.3 Primary Energy Consumption by Source, Table 12.1 Carbon Dioxide Emissions from Energy Consumption by Source

85. In addition, the increase in biomass used for energy and the increase in market share of wind power have further contributed to this 12% decarbonization through changing market shares of primary energy used.

86. These data show that reductions in energy intensity of the economy and in carbon intensity of energy consumption have been fundamental in reducing emissions of CO_2 from levels that would have occurred without these intensity reductions. In the next sections I describe federal policy actions that helped create these intensity reductions. I begin discussing energy efficiency, which reduced the energy intensity of the economy. Subsequently I discuss the policies that have encouraged the growth of low carbon or near-zero-carbon energy production technologies.

VII. Federal Programs and Policies Have Contributed Substantially to the Decarbonization of the U.S. Economy

87. Plaintiffs' experts and the Complaint assert that the federal government has done little to reduce GHG emissions.[59] However, beginning in 1973, federal policy changes have contributed substantially to the decarbonization of the U.S. economy, even while addressing the multiple competing fundamental policy objectives.

A. Affirmative Policy Steps Encouraging Energy Efficiency

88. The federal government has taken affirmative policy steps that have reduced emissions by increasing energy efficiency.

89. An example of such an affirmative policy was the Energy Policy and Conservation Act of 1975, which was motivated by the energy crisis of 1973–1974 and arguably was framed by the discussion in the *Project Independence Report*.[60] This act established two important efficiency standards programs that have had a significant impact on U.S. energy efficiency. The first is the CAFE Standards, which placed minimum efficiency standards on each manufacturer of new cars and light-duty trucks sold in the U.S.[61] The CAFE Standards were later strengthened by the Energy Independence and Security Act of 2007[62] and later by the Obama Administration.[63] The CAFE Standards have helped reduce the fuel consumption per mile of new vehicles by 57% from 1973 to 2013,[64] although some of these reductions would have come about because of increased gasoline prices and increased competition from makers of small foreign cars.

90. The Energy Policy and Conservation Act of 1975 also established federal appliance efficiency standards.[65] The program's standards and list of appliances were strengthened and expanded under the National Energy Conservation Policy Act of 1978, the National Appliance Energy Conservation Act of 1987, the Energy Policy Act of 1992, and the Energy Policy Act of

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[59] Complaint, ¶98, Hansen Report, pp. 3–4, and Declaration of James Gustave "Gus" Speth in Support of Plaintiffs' Response in Opposition to Defendants' Motion for Summary Judgment, June 27, 2018 ("Speth Declaration"), ¶10.
[60] Sweeney, p. 25.
[61] Sweeney, p. 25.
[62] Sweeney, p. 25.
[63] Sweeney, p. 25.
[64] Sweeney, p. 25.
[65] Sweeney, p. 137.

2005.[66] Currently, the efficiency standards are applied to products that account for more than 90%, 60%, and 30% of residential, commercial and industrial energy use, respectively.[67] In addition, several states have enacted their own efficiency standards. The appliance standards have helped to improve the efficiency of products such as refrigerators (which use 75% less energy relative to 1973, despite being larger), washing machines (which use 70% less energy relative to 1990), dishwashers (which use 40% less energy relative to 1990), and air conditioners (which use 50% less energy relative to 1990).[68]

91. Concurrent to the appliance efficiency standards program, the federal government, in particular the DOE, the Federal Trade Commission, and the EPA, launched information programs to encourage energy-use reduction.[69] In 1992, the EPA launched the Energy Star program, a voluntary program established to identify and promote energy-efficient products and buildings in order to reduce energy consumption, improve energy security, and reduce pollution.[70]

92. The federal government has relied heavily on a combination of strategies for appliances—technological advances funded by the DOE, advances by private sector manufacturers, appliance efficiency standards that progressively pushed and pulled newer technologies into the marketplace, and Energy Star labeling. Table 1 summarizes the federal equipment efficiency standards for appliances typically sold in the residential sector. Table 2 provides a list of appliances subject to equipment efficiency standards in the commercial/industrial sector.

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[66] Sweeney, p. 137.

[67] "Saving Energy and Money with Appliances and Equipment Standards in the United States," *U.S. Department of Energy*, January 2007, https://www.energy.gov/sites/prod/files/2017/01/f34/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-011917_0.pdf.

[68] "Saving Energy and Money with Appliances and Equipment Standards in the United States," *U.S. Department of Energy*, January 2007, https://www.energy.gov/sites/prod/files/2017/01/f34/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-011917_0.pdf.

[69] Sweeney, p. 128.

[70] Sweeney, p. 128.

Table 1. Residential National Appliance Standards

Product Covered	Initial Legislation	Last Standard Published	Compliance Date	Issued By	States With Standard[1]
Battery Chargers	EPACT 2005	2016	2018	DOE	CA, OR
Boilers	NAECA 1987	2016	2021	DOE	
Ceiling Fans	EPACT 2005	2017	2020	DOE	
Central Air Conditioners and Heat Pumps	NAECA 1987	2017	2023	DOE	
Clothes Dryers	NAECA 1987	2011	2015	DOE	
Clothes Washers	NAECA 1987	2012	2018	DOE	
Compact Audio Equipment					CA, CT, OR
Computers and Computer Systems				N/A	CA
Cooking Products	NAECA 1987	2009	2012	DOE	
Dehumidifiers	EPACT 2005	2016	2019	DOE	
Direct Heating Equipment[2]	NAECA 1987	2016	None	DOE	
Dishwashers[2]	NAECA 1987	2016	None	DOE	
DVD Players and Recorders					CA, CT, OR
External Power Supplies	EPACT 2005	2014	2016	DOE	CA
Faucets	EPACT 1992	1992	1994	Congress	CA, CO
Furnace Fans	EPACT 2005	2014	2019	DOE	
Furnaces	NAECA 1987	2007	2015	DOE	
Microwave Ovens	NAECA 1987	2013	2016	DOE	
Miscellaneous Refrigeration Products		2016	2019	DOE	CA
Pool Heaters	NAECA 1987	2010	2013	DOE	
Pool Pumps		2017	2021	DOE	AZ, CA, CT, WA
Portable Electric Spas					AZ, CA, CT, OR, WA
Refrigerators and Freezers	NAECA 1987	2011	2014	DOE	
Room Air Conditioners	NAECA 1987	2011	2014	DOE	
Showerheads	EPACT 1992	1992	1994	Congress	CA, CO
Televisions	NAECA 1987			N/A	CA, CT, OR
Toilets	EPACT 1992	1992	1994	Congress	CA, CO, GA, TX
Water Heaters	NAECA 1987	2010	2015	DOE	

Source: Appliance Standards Awareness Project

Note:
[1] In addition to federal standards, some states have set their own standards, including for some appliances in which the federal standards don't yet exist.
[2] DOE is required to issue either a proposed revised standard or a determination that no change is warranted no later than six years after the last final rule amending a standard. Products for which a publication date is listed in the table for the last standard but for which no compliance date is listed are those for which DOE determined that no change to the standard was warranted.

Table 2. Commercial and Industrial National Appliance Standards

Product Covered	Initial Legislation	Last Standard Published	Compliance Date	Issued By	States With Standard[1]
Automatic Commercial Ice Makers	EPACT 2005	2015	2018	DOE	
Boilers, Commercial	EPACT 1992	2009	2012	DOE	
Clothes Washers, Commercial	EPACT 2005	2014	2018	DOE	
Commercial CAC and HP (65,000 Btu/hr to 760,000 Btu/hr)	EPACT 1992	2016	2018	DOE	
Commercial CAC and HP (<65,000 Btu/hr)	EPACT 1992	2015	2017	DOE	
Commercial CAC and HP (Water- and Evaporatively-Cooled)	EPACT 1992	2012	2013	DOE	
Commercial Refrigeration Equipment	EPACT 2005	2014	2017	DOE	
Commercial Warm Air Furnaces	EPACT 1992	2016	2023	DOE	
Commercial Water Heaters	EPACT 1992	2001	2003	DOE	
Computer Room Air Conditioners	EPACT 1992	2012	2013	DOE	
Distribution Transformers: Liquid-Immersed	EPACT 1992	2013	2016	DOE	
Distribution Transformers: Low-Voltage Dry-Type	EPACT 2005	2013	2016	DOE	
Distribution Transformers: Medium-Voltage Dry-Type	EPACT 1992	2013	2016	DOE	
Electric Motors	EPACT 1992	2014	2016	DOE	
Hot Food Holding Cabinets					CA, CT, DC, MD, NH, OR, RI, WA
Packaged Terminal AC and HP	EPACT 1992	2015	2017	DOE	
Pre-Rinse Spray Valves	EPACT 2005	2016	2019	DOE	
Pumps, Commercial and Industrial	EPACT 1992	2016	2020	DOE	
Single Package Vertical Air Conditioners and Heat Pumps	EPACT 1992	2015	2019	DOE	
Small Electric Motors	EPACT 1992	2010	2015	DOE	
Unit Heaters	EPACT 2005	2005	2008	Congress	
Urinals	EPACT 1992	1992	1994	Congress	CA, CO, TX
Vending Machines	EPACT 2005	2016	2019	DOE	
Walk-In Coolers and Freezers	EISA 2007	2014	2017	DOE	
Water Dispensers					CA, CT, DC, MD, NH, OR, RI, WA
Water-Source Heat Pumps	EPACT 1992	2015	2015	DOE	

Source: Appliance Standards Awareness Project

Note:
[1] In addition to federal standards, some states have set their own standards, including for some appliances in which the federal standards don't yet exist.

93. In the mid-1970s, NASA began the Aircraft Energy Efficiency Program ("AEEP") to make flight operations more efficient.[71] The AEEP led directly to the development of the winglet, which increased fuel efficiency of aircraft by 6%–7% and was adopted by the private

[71] Sweeney, p. 40.

sector.[72] Additional AEEP projects led to significant improvements in the fuel efficiency of commercial airplanes. An estimate from 1999 suggested that aircraft energy efficiency improved since the mid-1970s by an average of 3%–4% each year, reducing the fuel required for a seat by 50%.[73]

94. The federal government also enacted federal lighting standards as part of the Energy Independence and Security Act of 2007 ("EISA"), mandating that general service incandescent lamps must use roughly at least 27% less energy by 2014 compared to "old-style" incandescent lightbulbs, and that most lightbulbs must be 60%–70% more efficient than the standard incandescent lights by 2020.[74] Essentially, the EISA prohibited sale of lightbulbs that do not meet a minimum efficiency standard of 45 lumens per watt, effective January 2020.[75] The DOE estimated that these regulations will result in energy savings of 14 quadrillion BTU over 30 years (2008–2038).[76] Table 3 provides a list of lighting products subject to efficiency standards.

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[72] Sweeney, p. 40.
[73] Mark D. Bowles, "*The 'Apollo' of Aeronautics: NASA's Aircraft Energy Efficiency Program 1973 – 1987*" (Washington, DC: NASA, 2010), p. xv, https://www.nasa.gov/pdf/601247main_ApolloAeronautics-ebook.pdf.
[74] Sweeney, p. 137.
[75] Colleen L.S. Kantner et al., "Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps," *Berkeley Lab*, LBNL-1007090, January 2017, p. 1, https://www.eenews.net/assets/2017/05/04/document_gw_04.pdf.
[76] Colleen L.S. Kantner et al., "Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps," *Berkeley Lab*, LBNL-1007090, January 2017, p. 3, https://www.eenews.net/assets/2017/05/04/document_gw_04.pdf.

Table 3. Lighting National Appliance Standards

Product Covered	Initial Legislation	Last Standard Published	Compliance Date	Issued By	States With Standard[1]
Candelabra & Intermediate Base Incandescent Lamps		2007	2012	Congress	
Ceiling Fan Light Kits	EPACT 2005	2016	2019	DOE	
Compact Fluorescent Lamps	EPACT 2005	2005	2006	Congress	
Deep-Dimming Fluorescent Ballasts					CA
Fluorescent Lamp Ballasts	NAECA 1988	2011	2014	DOE	
General Service Fluorescent Lamps	EPACT 1992	2015	2018	DOE	
General Service Lamps	EISA 2007	2007	2012	Congress	
HID Lamps	EPACT 1992	2015		DOE	
High Light Output Double-Ended Quartz Halogen Lamps					OR
Illuminated Exit Signs	EPACT 2005	2005	2006	Congress	
Incandescent Reflector Lamps	EPACT 1992	2015	None	DOE	
Mercury Vapor Lamp Ballasts	EPACT 2005	2005	2008	Congress	
Metal Halide Lamp Fixtures	EISA 2007	2014	2017	DOE	
Small-Diameter Directional Lamps					CA
Torchiere Lighting Fixtures	EPACT 2005	2005	2006	Congress	
Traffic Signals	EPACT 2005	2005	2006	Congress	

Source: Appliance Standards Awareness Project

Note:
[1] In addition to federal standards, some states have set their own standards, including for some appliances in which the federal standards don't yet exist.

95. In addition to standards, the federal government sponsors R&D programs designed to enhance energy efficiency. One example of the many R&D successes stemming from energy efficiency research is in refrigeration. Prior to 1973, the electricity used by new refrigerators installed in U.S. households was increasing year after year. In 1950 the average new refrigerator used about 400 kWh per year; that had increased to about 1,800 kWh per year as of 1973.[77]

96. As a direct response to the increasing use of electricity in refrigerators, in 1977 the DOE, through Oak Ridge National Laboratory, supported research into compressor efficiency, with an intention to decrease electricity use by refrigerator-freezers and supermarket refrigeration

[77] "Energy Research at DOE, Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000," Committee on Benefits of DOE R&D on Energy Efficiency and Fossil Energy, Board on Energy and Environmental Systems, Division on Engineering and Physical Sciences, National Research Council (Washington, DC: National Academy Press, 2001) p. 97.

systems. The DOE "targeted both improved components, starting with the electricity-intensive refrigerator compressor, and computer tools for analyzing refrigerator design options. Early successes included a compressor system that achieved 44 percent efficiency improvement over the technology commonly used in refrigerators of the late 1970s."[78]

97. Subsequently, actions by many organizations collectively transformed the refrigerator market so that now the average new refrigerator uses less than 500 kWh per year, even though the average size of new refrigerators is larger than in 1973.[79] After the technological advances, these organizations created an innovative incentive for refrigerator manufacturers to conduct R&D targeted toward energy efficiency, called the Super Efficient Refrigerator Program ("SERP"). The first "Golden Carrot" program to be implemented in the U.S., SERP was a competition among refrigerator manufacturers designed to accelerate development and commercialization of super-efficient refrigerators. SERP featured a $30 million award, competitively given to the refrigerator manufacturer that could develop, distribute, promote, and sell the most energy-efficient, CFC-free refrigerator/freezer in the most cost-effective manner possible.[80] Whirlpool was the ultimate winner, and the SERP led to other efforts to combine federal R&D efforts with upstream manufacturing incentives.[81]

98. Once economically attractive reductions in energy use were possible, refrigerator manufacturers embedded this technology into some models they put on the market. Utilities, particularly those part of SERP, had promised to provide rebates in their service areas, thereby providing a market pull to increase market share for the winner.[82]

99. Once energy efficient refrigerators were successfully commercialized, the State of California imposed a sequence of appliance efficiency standards for refrigerators sold in

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[78] "Energy Research at DOE, Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000," Committee on Benefits of DOE R&D on Energy Efficiency and Fossil Energy, Board on Energy and Environmental Systems, Division on Engineering and Physical Sciences, National Research Council, (Washington, DC: National Academy Press, 2001) pp. 95–96.
[79] Sweeney, p. 23.
[80] With consent of public utilities commissions, six utilities formed SERP Inc. for the Golden Carrot program and ultimately 18 other public and private utilities, in partnership with the EPA and environmental groups, joined the effort. The utilities promised to provide rebates in their service areas, thereby increasing the market share for the winner. Sweeney, p 140, fn. 19.
[81] See National Renewable Energy Laboratory, NREL/TP-461-7281, "The Super Efficient Refrigerator Program: Case Study of a Golden Carrot Program," July 1985, http://www.nrel.gov/docs/legosti/old/7281.pdf.
[82] Sweeney, p. 141.

California. Additional private sector and public sector research was further motivated by these standards, and this research led to further efficiency improvements.[83]

100. In turn, those additional efficiency improvements led to even tighter California efficiency standards. Federal standards followed, each requiring lower electricity use than the previous standards. As a result of this combination of private sector and public sector actions, the average electricity consumption of a new refrigerator decreased 72% from 1973–2014.[84]

101. Furthermore, the Energy Star voluntary program, described above, successfully encouraged manufacturers to market refrigerators that qualify for the Energy Star label in addition to those that just meet the minimum regulatory requirement. Energy Star has encouraged a significant fraction of buyers to purchase refrigerators carrying its label.[85]

102. It was this combination of factors—technological advances funded by the DOE, advances by private sector refrigerator manufacturers aided by funding from utilities through state public utility commission-approved programs, appliance efficiency standards that progressively pushed and pulled newer technologies into the marketplace, and Energy Star labeling—that reversed the trend of annual increases in energy use by new refrigerators and led to the increases in energy efficiency. The net result has been a fundamental transformation of the refrigerator market and a substantial reduction in energy use for refrigeration.

103. Finally, the federal government introduced tax credits and incentives for energy efficient buildings and technologies with the Energy Policy Act of 2005, and extended them under the Energy Improvement and Extension Act of 2008, the American Recovery and Reinvestment Act of 2009, and the Tax Increase Prevention Act of 2014.[86]

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[83] Sweeney, p. 141.
[84] Sweeney, p. 141.
[85] Sweeney, pp. 141–142.
[86] Sweeney, p. 151.

104. The various federal regulatory laws and tax incentives promoting energy efficiency are summarized in Table 4, below. That table shows that energy efficiency standards and tax incentives were signed into law by U.S. presidents in both Republican and Democratic administrations. In fact, all but one Republican and one Democratic president since the Ford administration signed such energy efficiency laws.

Table 4. Selected Federal Efficiency Standards and Tax Credits

Act/Action	Year	Key Provision	President	Party
Automobile Efficiency Standards				
Energy Policy and Conservation Act (ECPA)	1975	First CAFE standards	Gerald Ford	R
Energy Policy and Conservation Act (ECPA)	2007	Allowed CAFE standards to be raised	George W. Bush	R
Administrative Action	2012	Raised CAFE standards	Barack Obama	D
Appliance Standards				
Energy Policy and Conservation Act (ECPA)	1975	First Federal appliance efficiency standards	Gerald Ford	R
National Energy Conservation Policy Act	1978	Required manufacturer impact analysis	Jimmy Carter	D
National Appliance Energy Conservation Act	1987	Expanded regulatory authority	Ronald Reagan	R
Energy Policy Act	1992	Expanded regulatory authority	George H.W. Bush	R
Energy Policy Act	2005	Expanded regulatory authority	George W. Bush	R
Energy Independence and Security Act	2007	Lighting efficiency standards	George W. Bush	R
Tax Credits				
Energy Policy Act	2005	Home energy efficiency standards	George W. Bush	R
Energy Policy Act	2005	Tax credit for energy efficient vehicles	George W. Bush	R
Energy Improvement and Extension Act	2008	Extended time of home efficiency tax credit	George W. Bush	R
American Recovery and Reinvestment Act	2009	Extended time of home efficiency tax credit	Barack Obama	D
Tax Increase Prevention Act	2014	Extended time of home efficiency tax credit	Barack Obama	D

Source: James L. Sweeney, *Energy Efficiency: Building a Clean, Secure Economy* (Stanford, CA: Hoover Institution Press, 2016)

B. Affirmative Policy Steps Encouraging Low Carbon Energy Sources

105. The federal government has also taken affirmative policy steps to facilitate the development and adoption of renewable energy sources, such as hydropower, wind, solar, and nuclear power, each of which produce very low carbon or zero-carbon energy.

106. The federal government has continued its role as a major owner/operator of about one-half of the total hydropower capacity in the U.S.[87] From 1990–2017, hydroelectric generation

[87] Federal Energy Regulatory Commission Report, "Hydropower Primer," February 2017, https://www.ferc.gov/legal/staff-reports/2017/hydropower-primer.pdf.

accounted for about 8% of electricity generation in the U.S., varying from year-to-year based on precipitation.[88]

107. In the Pacific Northwest, hydroelectric projects provide a large percentage of power. For example, Bonneville Power Administration ("BPA"), a federal power marketing administration based in the Pacific Northwest, relies heavily on hydropower.[89] BPA is part of the DOE, but is self-funding and covers its costs by selling its products and services.[90] BPA markets wholesale electrical power from 31 federal hydroelectric projects in the Pacific Northwest, one nonfederal nuclear plant, and several small nonfederal power plants.[91] BPA provides about 28 percent of the electric power used in the Pacific Northwest and its resources—primarily hydroelectric—make BPA power nearly carbon-free.[92]

108. The federal government has continued to take affirmative policy steps to advance nuclear power, another very-low-carbon generator for electricity. A central organization is the DOE's Office of Nuclear Energy ("NE"). NE's mission is "to advance nuclear power to meet the nation's energy, environmental, and national security needs."[93]

> "Under the guidance of three research objectives, NE resolves barriers to technical, cost, safety, security, and proliferation resistance through early-stage research, development, and demonstration to:
>
> - Enhance the long-term viability and competitiveness of the existing U.S. reactor fleet.
> - Develop an advanced reactor pipeline.
> - Implement and maintain national strategic fuel cycle and supply chain infrastructure."

[88] U.S. Energy Information Administration, "July 2018 Monthly Energy Review," Tale 7.2b Electricity Net Generation: Electric Power Sector.
[89] "About Us," *Bonneville Power Administration*, undated, https://www.bpa.gov/news/AboutUs/Pages/default.aspx.
[90] "About Us," *Bonneville Power Administration*, undated, https://www.bpa.gov/news/AboutUs/Pages/default.aspx.
[91] "About Us," *Bonneville Power Administration*, undated, https://www.bpa.gov/news/AboutUs/Pages/default.aspx.
[92] "About Us," *Bonneville Power Administration*, undated, https://www.bpa.gov/news/AboutUs/Pages/default.aspx.
[93] "About Us," *Office of Nuclear Energy*, undated, https://www.energy.gov/ne/about-us, accessed August 11, 2018.

109. Nuclear power has provided about 20% of electrical generation in the U.S. since 1990, up from 4% in 1973.[94] That increase has been the result of post-R&D electric utility investments, sponsored in large part by the federal government.[95]

110. The DOE has provided funding for the development of photovoltaic (solar) cells through industry, research groups, and national laboratories. In 1977 the federal government created the Solar Energy Research Institute ("SERI"), a federal facility dedicated to finding and improving ways to harness and use energy from the sun. In 1991, SERI was elevated to national laboratory status and renamed the National Renewable Energy Lab.[96]

111. In 1999, the Office of Energy Efficiency and Renewable Energy launched the Wind Powering America Initiative, which sought to advance the development and use of wind energy throughout America. The program adopted two objectives: deliver 5% of the nation's electricity from wind power by 2020, and deliver 5% of the federal government's electricity purchases through wind power by 2010.[97]

112. In 2011, the DOE's Solar Energy Technologies Office ("SETO") launched the SunShot Initiative with the objective of making solar electricity costs competitive with other generation sources by 2020, without subsidies. Meeting that goal would allow the private sector to implement broad-scale solar. In September 2017, SETO announced the utility-scale solar goal had been met three years ahead of schedule. SETO is continuing to work to lower the cost of solar energy, with the goal of cutting its cost in half by 2030.[98]

113. New installations of wind and solar electricity generation capacity have grown greatly since 2010 as a result of actions by private sector entities within the U.S., by private and public sectors entities in other countries, by state and local governments, and by the federal government. In 2010, new installations of wind and solar capacity accounted for 28% of total

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[94] U.S. Energy Information Administration, "July 2018 Monthly Energy Review," Tale 7.2b Electricity Net Generation: Electric Power Sector.

[95] "US Nuclear Policy," *World Nuclear Association*, May 2018, http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power-policy.aspx, accessed August 3, 2018.

[96] "EERE Timeline," *Office of Energy Efficiency & Renewable Energy*, undated, https://www.energy.gov/eere/timeline/eere-timeline.

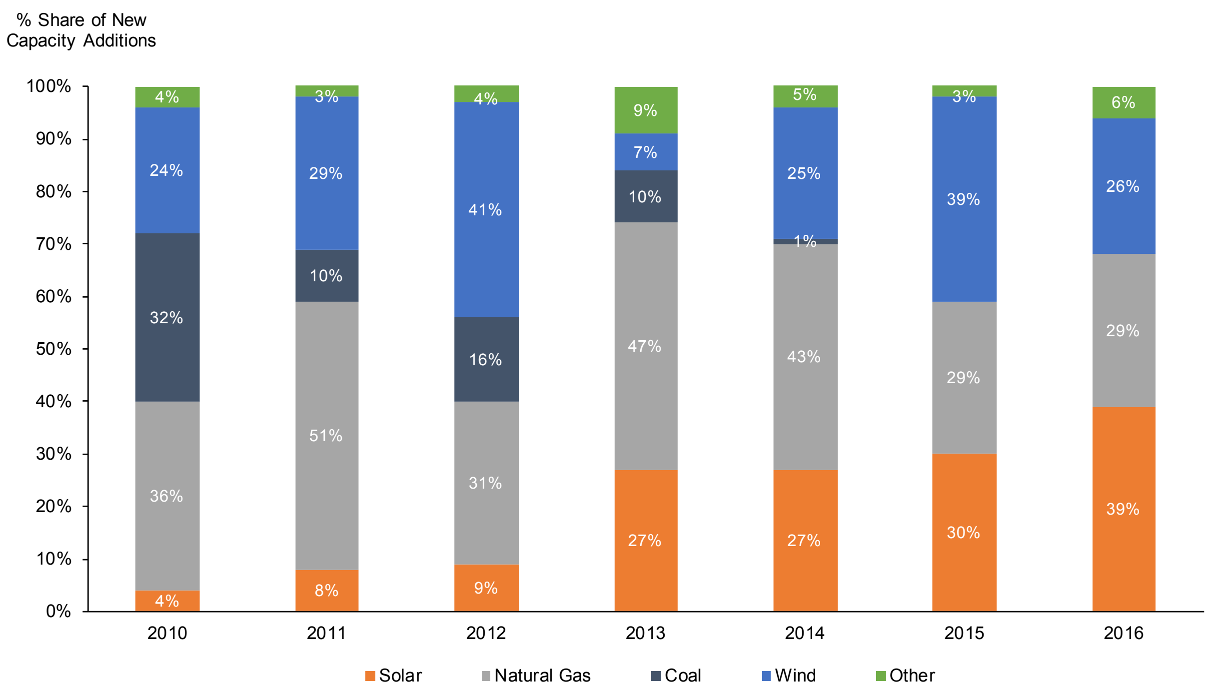
[97] "EERE Timeline," *Office of Energy Efficiency & Renewable Energy*, undated, https://www.energy.gov/eere/timeline/eere-timeline.

[98] "About the Solar Energy Technologies Office," *Solar Energy Technology Offices*, undated, https://www.energy.gov/eere/solar/about-solar-energy-technologies-office, accessed August 3, 2018.

new electricity generation capacity in the U.S., while coal accounted for 32% of new generation. In 2012 and 2013, wind and solar new capacity had grown to 50% and 34% of new electricity generation capacity, respectively, and coal had dropped to 16% and 10%. In 2015 and 2016, wind and solar new capacity had grown to 69% and 65% of new electricity generation capacity, respectively, and coal had dropped to zero in both years. Figure 7 shows these data, which are published by the Solar Energy Industries Association.[99]

Figure 7. New U.S. Electricity Generating Capacity Additions

2010–2016



Source: Solar Energy Industries Association Report, "Solar Market Insight Report 2016 Year In Review"

Note: Percentages shown may not sum to 100% due to rounding.

[99] "U.S. Solar Market Insight," *GTM Research*, undated, https://www.seia.org/research-resources/solar-market-insight-report-2016-year-review. Note that these data are based on generating capacity, not the amount of electricity that would be generated. Capacity factors of intermittent resources, wind and solar, are substantially lower than capacity factors of nuclear, natural gas, and coal facilities. A capacity factor is the ratio of actual production over a given time horizon, divided by the maximum possible (i.e., full capacity) production for the same period.

114. In 2015, the Obama administration announced the Clean Power Plan, which sought to cut GHG emissions from U.S. power stations by nearly one-third over 15 years. The Clean Power Plan also included provisions that would place significant emphasis on wind, solar, and other renewable energy sources.[100] The Supreme Court stayed implementation of the Clean Power Plan in February 2016, and the EPA under the Trump administration subsequently proposed to repeal the Clean Power Plan in 2017, citing concerns over the EPA's regulatory authority and other policy concerns.[101] More specific to the policy concerns, the EPA stated that repealing the measure would "facilitate the development of U.S. energy resources and reduce unnecessary regulatory burdens associated with the development of those resources."[102] This example illustrates the trade-offs that the executive branch and federal agencies consider when setting energy policy.

115. Tax credits and federal funding for renewable energy use, research, and development have existed since the National Energy Act of 1978 and were expanded or extended under the Energy Security Act of 1980, the Energy Policy Act of 1992, the Energy Independence and Security Act of 2007, the Energy Improvement and Extension Act of 2008, and the American Recovery and Reinvestment Act of 2009.[103]

116. Since 1992, the U.S. has offered the production tax credit ("PTC") to eligible renewable sources of electricity including wind and solar facilities.[104] Using data from Aldy et al. (2018) on wind farm construction, capacities, realized capacity factors, and PTC-eligibility, a back-of-the-envelope calculation shows that there were roughly $2 billion in PTC payments during the 2014

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[100] "Climate Change: Obama Unveils Clean Power Plan," *BBC*, August 3, 2015, http://www.bbc.com/news/world-us-canada-33753067, accessed August 3, 2018.
[101] Lisa Friedman and Brad Plumer, "E.P.A. Announces Repeal of Major Obama-Era Carbon Emissions Rule," *New York Times*, October 9, 2017, https://www.nytimes.com/2017/10/09/climate/clean-power-plan.html, accessed August 3, 2018.
[102] Lisa Friedman and Brad Plumer, "E.P.A. Announces Repeal of Major Obama-Era Carbon Emissions Rule," *New York Times*, October 9, 2017, https://www.nytimes.com/2017/10/09/climate/clean-power-plan.html, accessed August 3, 2018.
[103] "History of Major Energy Policy Landmarks," Department of Geography, Penn State, undated, https://www.e-education.psu.edu/geog432/node/116, accessed August 11, 2018. See also House Resolution 6049, 110th Congress, 2009.
[104] 26 U.S.C. § 45a.

calendar year for wind farms alone.[105] Accounting for solar, biomass, and other renewable production tax credits would increase this number.[106]

117. Renewable energy facilities that came online after January 1, 2009 can also elect to receive an investment subsidy (Section 1603 grant) in lieu of the PTC.[107] The Section 1603 grants cover up to 30% of the investment costs of a new facility, and between 2009 and 2017 payments have totaled over $26 billion.[108] This represents more than $3.25 billion on average each year.

118. Plaintiffs' object to the subsidies paid for fossil fuel productions. However, a rough comparison of the subsidy per BTU (a quantity of heat) of renewable energy production to fossil fuel production shows that the renewable energy subsidy is more than twice as large.

119. The Complaint lists $13.2 billion of production and consumption subsidies for fossil fuels.[109] In 2014, a total of 69.6 quadrillion BTUs were produced from fossil fuels in the U.S.[110] Taking the $13.2 billion of subsidies listed in the Complaint as given and dividing it by 69.6 quadrillion BTUs results in $0.19 of subsidies per million BTU (MBTU). For context, a gallon of gasoline has a heating value of 120,429 BTU;[111] 8.3 gallons of gasoline have a heating value of a million BTU. Thus the average subsidy using the figure in the Complaint is about 2 cents per gallon of gasoline.[112]

120. Total renewable production (including hydroelectric, geothermal, and biomass production) was 11.14 quadrillion BTU. Adding together the roughly $2 billion in PTC

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[105] This is calculated taking into account the $23/MWh production tax credit, along with 423 PTC-eligible plants assuming an 81.15 MW average capacity per plant and a 0.34 average capacity factor for each plant. See Joseph E. Aldy et al., "Investment Versus Output Subsidies: Implications of Alternative Incentives for Wind Energy," December 2016, Table 1.

[106] 2014 is the most recent data available in the Aldy et al. paper. See Joseph E. Aldy et al., "Investment Versus Output Subsidies: Implications of Alternative Incentives for Wind Energy," December 2016.

[107] Joseph E. Aldy et al., "Investment Versus Output Subsidies: Implications of Alternative Incentives for Wind Energy," December 2016.

[108] "Final Overview of the §1603 Program," *U.S. Treasury*, March 1, 2018, https://www.treasury.gov/initiatives/recovery/Pages/1603.aspx.

[109] Complaint, ¶¶173, 174.

[110] U.S. Energy Information Administration, "July 2018 Monthly Energy Review," Table 1.1 Primary Energy Overview.

[111] The motor gasoline considered contains about 10% fuel ethanol by volume. "Energy Units and Calculations Explained," U.S. Energy Information Administration. https://www.eia.gov/energyexplained/index.php?page=about_energy_units, accessed August 11, 2018.

[112] Note that ($0.19 / 1 MBTU) / (8.3 gallons / 1 MBTU) = $0.02 / gallon

expenditure for wind power and the $3.25 billion annual average Section 1603 grant expenditures for renewables and dividing by total renewable production, one would arrive at $0.47 per million BTU. This does not include PTC expenditure for other renewable electricity sources besides wind power. These calculations err on the side of overestimating the relative size of the fossil fuel subsidy, and still show that renewable subsidies are over two times larger than fossil fuel subsidies on a per BTU basis.[113]

C. CO_2 from Fossil Fuel Production

121. Other actions by the federal government had the impact of reducing the amount of CO_2 from fossil fuel production.

122. One approach to reducing the impact of CO_2 from fossil fuel production is carbon capture and storage ("CCS").[114] CCS is an advanced concept which aims to reduce the CO_2 emitted into the atmosphere by capturing it at the point it would otherwise be released, or by direct air capture. Since 1997, the DOE's Office of Fossil Energy has run an active carbon storage program.[115] This program has significantly advanced the CCS knowledge base through a diverse portfolio of applied research projects:[116]

> "The portfolio includes industry cost-shared technology development projects, university research grants, collaborative work with other national laboratories, and research conducted in-house through the National Energy Technology Laboratory's Research and Innovation Center.
>
> The primary focus of the Program going forward is on early-stage R&D to develop coupled simulation tools, characterization methods, and monitoring technologies that will improve storage efficiency, reduce overall cost and project risk, decrease subsurface uncertainties, and identify ways to ensure that operations are safe, economically viable, and environmentally benign.
>
> Key Program goals include:
>
> - Determining the CO_2 storage resource potential of on and offshore oil, gas, and saline bearing formations

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[113] In particular, I have only listed a few of the more well-known subsidies for renewable power investment and production and have not attempted to compile a comprehensive list of all renewable subsidies.

[114] Carbon capture and storage is also referred to as "carbon capture and sequestration."

[115] "Carbon Storage Research," *Department of Energy*, https://www.energy.gov/fe/science-innovation/carbon-capture-and-storage-research, accessed August 3, 2018.

[116] "Carbon Storage Research," *Department of Energy*, https://www.energy.gov/fe/science-innovation/carbon-capture-and-storage-research, accessed August 3, 2018.

- Improving carbon storage efficiency and security by advancing new and early-stage monitoring tools and models
- Improving capabilities to evaluate and manage environmental risks and uncertainty through integrated risk-based strategic monitoring and mitigation protocols
- Disseminating findings and lessons learned to the broader CCS community and key stakeholders."

123. Three components[117]—"Storage Infrastructure, Core Storage Research and Development, and Strategic Program Support"—"address significant technical challenges in order to meet program goals that support the scale-up and widespread deployment of CCS."

124. In 1975 President Ford signed a bill that repealed the percentage depletion allowance for large companies.[118] Elimination of the percentage depletion allowance for large companies reduces incentives for these companies to produce oil and gas. However, in 2005, President Bush signed the Energy Policy Act, which expanded the percentage depletion allowance to apply to a larger group of drillers. In 2013, the percentage depletion allowance provided an annual deduction of 15% of revenues from oil and gas wells, but only of independent producers and royalty owners.[119] It is not available for integrated companies.[120] The small independent producers of oil and gas, to which the percentage depletion allowance currently applies, account for just 19% of oil and 12% of natural gas production.[121]

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[117] "Carbon Storage Research," *Department of Energy*, https://www.energy.gov/fe/science-innovation/carbon-capture-and-storage-research, accessed August 3, 2018.
[118] See "Congress Votes Largest Tax Cut in History," *CQ Almanac 1975* (Washington, DC: Congressional Quarterly, 1976), pp. 95–111, http://library.cqpress.com/cqalmanac/cqal75-1213141. "[Percentage] [d]epletion is a form of depreciation for mineral resources that allows for a deduction from taxable income to reflect the declining production of reserves over time." "Percentage Depletion," *Energy Tax Facts*, undated, http://energytaxfacts.com/wp-content/uploads/2017/10/Fact-Sheet-Percentage-Depletion.pdf.
[119] "Percentage Depletion," *Energy Tax Facts*, undated, http://energytaxfacts.com/wp-content/uploads/2017/10/Fact-Sheet-Percentage-Depletion.pdf.
[120] "Percentage Depletion," *Energy Tax Facts*, undated, http://energytaxfacts.com/wp-content/uploads/2017/10/Fact-Sheet-Percentage-Depletion.pdf.
[121] "Percentage Depletion," *Energy Tax Facts*, undated, http://energytaxfacts.com/wp-content/uploads/2017/10/Fact-Sheet-Percentage-Depletion.pdf.

D. Participation in International Climate Change Initiatives

125. Starting with the first "Earth Summit," held in Rio de Janeiro in 1992, the U.S. has been engaged in international cooperation to address global climate change.[122] The stated objective of the United Nations Framework Convention on Climate Change ("UNFCCC"), signed by President George H. W. Bush and the leaders of 153 other nations, was "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[123] Not only did the U.S. participate in these meetings and sign the treaty, but it also took the lead in implementing its objectives.[124, 125]

126. In 1997, the U.S. participated actively in the development of the Kyoto Protocol, with Vice President Al Gore personally attending the meetings and instructing the U.S. negotiating teams "to show increased negotiating flexibility if a comprehensive plan can be put in place, one with realistic targets and timetables, market mechanisms, and the meaningful participation of key developing countries."[126] President Clinton signed the Kyoto Protocol in 1998,[127] but it was never ratified by the Senate.

127. The Kyoto Protocol put the obligation to reduce current emissions on developed countries and not on developing countries. Before the Kyoto Protocol had been negotiated, the U.S. Senate unanimously passed the Byrd–Hagel Resolution in July 1997. That resolution made it

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[122] Sweeney, p. 85.

[123] "United Nations Framework Convention on Climate Change," United Nations, 1992, p. 4, https://unfccc.int/resource/docs/convkp/conveng.pdf.

[124] George Bush, "Statement on Signing the Instrument of Ratification for the United Nations Framework Convention on Climate Change," *The American Presidency Project*, October 13, 1992, http://www.presidency.ucsb.edu/ws/?pid=21611. See also James Brooke, "The Earth Summit; President, in Rio, Defends His Stand on Environment," *New York Times*, June 13, 1992, https://www.nytimes.com/1992/06/13/world/the-earth-summit-president-in-rio-defends-his-stand-on-environment.html, accessed August 6, 2018.

[125] From 2016 – 2017, the United States was the largest contributor to the UNFCCC at 21%. See "Indicative Scales of contributions from parties to the Convention and the Kyoto Protocol for the biennium 2016-2017," *United Nations Climate Change Secretariat*, December 2015, https://unfccc.int/sites/default/files/scale.pdf. For 1996-1997, the United States contribution was 25%. See "Report of the Conference of the Parties on Its First Session, Held at Berlin from 28 March to 7 April 1995," United Nations Framework Convention on Climate Change, 1995, https://unfccc.int/resource/docs/cop1/07a01.pdf#page=44.

[126] Al Gore, "Kyoto Climate Change Conference," *Clinton Whitehouse Archive*, December 8, 1997, https://clintonwhitehouse3.archives.gov/WH/EOP/OVP/speeches/kyotofin.html, accessed August 3, 2018. See video at https://www.youtube.com/watch?v=oKRJAlT4dqw.

[127] Laurie Goering, "Clinton Signs Pact on Global Warming," *Chicago Tribune*, November 13, 1998, http://articles.chicagotribune.com/1998-11-13/news/9811130120_1_greenhouse-gas-emissions-greenhouse-gases-global-warming, accessed August 3, 2018.

clear that the Senate would not ratify the Kyoto Protocol unless the agreement also mandated specific commitments from developing countries and would not ratify the Kyoto Protocol if it would result in serious harm to the U.S. economy.[128]

128. In this example, the outcome was based on the checks and balances built into the U.S. system of government. Although the president and vice president supported the Kyoto Protocol, the Senate did not.

129. The U.S. has continued to participate in the Conference of the Parties ("COP") of the UNFCCC. The COP is the annual decision-making body of the Convention. The delegates to the annual COPs review implementation of the UNFCCC and negotiate legal instruments and international agreements to implement the UNFCCC.[129]

130. At the 2015 COP in Paris, the 185 national parties came to particularly significant agreements to curb CO_2 and other GHG emissions and to mitigate impacts of global climate change. Each nation, including the U.S., committed to Nationally Determined Contributions ("NDCs"). The U.S. committed to "reduce its greenhouse gas emissions by 26-28 percent below the 2005 level in 2025, and to make 'best efforts' to reduce emissions by 28 percent."[130]

131. President Obama signed the Paris Agreement in 2016.[131] However, he did not ask for Senate ratification. The White House asserted that the President has the legal authority to ratify the accord without a Senate vote, arguing that the Paris Agreement was merely an "executive agreement."[132]

132. On June 1, 2017 President Trump announced that the U.S. would cease all participation in the Paris Agreement. President Trump stated that "[t]he Paris accord is very unfair at the

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[128] Senate Resolution 98, 105th Congress, 1997.
[129] "Becoming a UNFCCC delegate: what you need to know," *International Institute for Environment and Development*, 2016, p. 10, http://pubs.iied.org/pdfs/17385IIED.pdf, accessed August 3, 2018.
[130] "What is the U.S. Commitment in Paris?" *State of the Planet*, December 11, 2015, http://blogs.ei.columbia.edu/2015/12/11/what-is-the-u-s-commitment-in-paris/, accessed August 3, 2018.
[131] Tanya Somanader, "President Obama: The United States Formally Enters the Paris Agreement," *Obama Whitehouse Archives*, September 3, 2016, https://obamawhitehouse.archives.gov/blog/2016/09/03/president-obama-united-states-formally-enters-paris-agreement, accessed August 3, 2018.
[132] Valerie Richardson, "White House Defends Obama Evading Senate on Paris Climate Deal," *Washington Times*, August 29, 2016, https://www.washingtontimes.com/news/2016/aug/29/obama-will-bypass-senate-ratify-paris-climate-acco/, accessed August 3, 2018.

highest level to the United States."[133] At the time he announced plans to withdraw from the Paris accord, President Trump also stated an intent to seek to renegotiate that agreement on terms more favorable to the U.S.[134] He went on to state: "The Paris accord will undermine our economy," and that it "puts us at a permanent disadvantage."[135]

133. This example underscores the tensions between economic and climate goals. One president took actions consistent with placing more emphasis on the fundamental environmental objective in signing the Paris Agreement, but did not ask the Senate whether it would ratify the agreement. The next president took actions consistent with placing more emphasis on the fundamental economic goals.

E. The Federal Government Has Adopted Complex Energy Policy Strategies to Address Multiple Policy Goals

134. Various U.S. presidents have had complex energy policy strategies that include multiple actions and policy instruments to reduce climate change, maintain security, and promote the economy, balancing the three objectives.

135. Most recently, President Obama, in his 2013 State of the Union address, reviewed U.S. energy progress since he had taken office and described an "all-of-the-above" approach for further progress. The accompanying White House Fact Sheet described the impacts of the "all-of-the-above" approach on the economy, energy security and the environment:[136]

> "Since President Obama took office, oil and gas production has increased each year, while oil imports have fallen to a 20-year low; renewable electricity generation from wind, solar, and geothermal sources has doubled; and our emissions of the dangerous carbon pollution that threatens our planet have fallen to their lowest level in nearly two decades. In short, the President's approach is working. It's a winning strategy for the economy, energy security, and the environment."

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[133] Bamini Chakraborty, "Paris Agreement on Climate Change: US Withdraws as Trump Calls it 'Unfair,'" *Fox News*, June 1, 2017, http://www.foxnews.com/politics/2017/06/01/trump-u-s-to-withdraw-from-paris-climate-pact-calls-it-unfair-for-america.html, accessed August 3, 2018.

[134] Michael D. Shear, "Trump Will Withdraw U.S. from Paris Climate Agreement," *New York Times*, June 1, 2017, https://www.nytimes.com/2017/06/01/climate/trump-paris-climate-agreement.html, accessed August 13, 2018.

[135] Bamini Chakraborty, "Paris Agreement on Climate Change: US Withdraws as Trump Calls it 'Unfair,'" *Fox News*, June 1, 2017, http://www.foxnews.com/politics/2017/06/01/trump-u-s-to-withdraw-from-paris-climate-pact-calls-it-unfair-for-america.html, accessed August 3, 2018.

[136] White House Press Release, "Fact Sheet: President Obama's Blueprint for a Clean and Secure Energy Future," March 15, 2013, https://www.whitehouse.gov/the-press-office/2013/03/15/fact-sheet-president-obama-s-blueprint-clean-and-secure-energy-future, accessed August 3, 2018.

136. This "all-of-the-above" approach, taking into account impacts on the economy, energy security, and the environment, has remarkable parallels to the *Project Independence Report* and the many actions from President Ford's administration, such as legislatively creating the CAFE standards for light duty cars and trucks.

137. President George W. Bush was very explicit in describing the overall strategy of his administration. In announcing his "Clear Skies and Global Climate Change Initiatives," he summarized his approach to addressing global climate change, an approach that stressed a positive relationship between economic growth and creating instruments to protect the environment:[137]

> "Addressing global climate change will require a sustained effort, over many generations. My approach recognizes that sustained economic growth is the solution, not the problem – because a nation that grows its economy is a nation that can afford investments in efficiency, new technologies, and a cleaner environment."

138. In his announcement, President George W. Bush proposed a set of specific actions in support of his overall strategy, actions that for the most part were implemented:[138]

> • **New 10 Percent Tax Credit for Co-Generation (Combined Heat and Power Systems).** The President has proposed a new 10 percent tax credit for investments in combined heat and power systems between 2002 and 2006….
>
> • **First-Ever Tax Credit for Residential Solar Energy Systems.** The President has proposed a new 15 percent tax credit for individuals who purchase photovoltaic equipment or solar water heating systems used in a residence, up to a maximum credit of $2,000 for each type of equipment….
>
> • **Expanded Tax Credit for Electricity Produced from Wind or Biomass.** The President has proposed extending and modifying the tax credit for electricity produced from wind or biomass….
>
> • **Tax Credit for New Methane Landfill Projects**. The President has proposed encouraging the development of a new alternative source of energy by providing tax credits for energy produced from landfill gas….
>
> • **New Tax Credit for New Hybrid or Fuel-Cell Vehicles.** The President has proposed a new temporary tax credit of up to $4,000 for the purchase of new hybrid vehicles and up to $8,000 for the purchase of fuel cell vehicles between 2002 and 2007….

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[137] White House Press Release, "Global Climate Change Policy Book," 2002, https://georgewbush-whitehouse.archives.gov/news/releases/2002/02/climatechange.html, accessed August 3, 2018.
[138] White House Press Release, "Global Climate Change Policy Book," 2002, https://georgewbush-whitehouse.archives.gov/news/releases/2002/02/climatechange.html, accessed August 3, 2018.

• **Increased Funding for Geothermal Energy**. The President's 2003 budget proposal for the U.S. Geological Survey (USGS) supports alternative, non-fossil fuel energy development….

• **Increased Funding for Renewable Energy Resources on Public Lands.** The President's '03 budget proposal calls for a major effort by the Bureau of Land Management (BLM) to increase its renewable energy activities in support of the President's National Energy Policy….

• **EPA's 'Climate Leaders' Initiative**: EPA will launch a new, voluntary Climate Leaders program with a group of major companies….

• **Business Challenges.** The President challenges American businesses and industries to reduce emissions….

• **Transportation Programs**. The Administration is promoting the development of fuel-efficient motor vehicles and trucks, researching options for producing cleaner fuels, and implementing programs to improve energy efficiency….

• **Carbon Sequestration.** The President's FY '03 budget requests over $3 billion … as the first part of a ten year (2002-2011) commitment to implement and improve the conservation title of the Farm Bill, which will significantly enhance the natural storage of carbon….

VIII. Many Policy Options Suggested in the Complaint Have Been Implemented

139. Plaintiffs complain that many particular policy initiatives favored by Plaintiffs have not been accepted by Congress or federal administrations. For example, Plaintiffs very early in their complaint assert that policy initiatives proposed in the EPA study, *Policy Options To Stabilizing Global Climate* (the "EPA Study") were not adopted:[139]

> "The United States Environmental Protection Agency ('EPA') in 1990 and the Congressional Office of Technology Assessment in 1991 prepared plans to significantly reduce our nation's CO_2 emissions, stop global warming, and stabilize the climate system for the benefit of present and future generations.
>
> …
>
> Defendants never implemented either plan."

140. In fact, many of the recommendations in the EPA Study were implemented by the federal government, contrary to Plaintiffs' assertion.

[139] Complaint, ¶3.

141. Much of the EPA Study argues the importance of energy efficiency and reducing the CO_2 emissions from what they would be otherwise.[140] The federal government has implemented many energy efficiency programs designed to accomplish precisely these goals. In fact, energy efficiency has been fundamental to the objectives articulated in the EPA Study and has led to large decarbonization of the U.S. economy.

142. The EPA Study suggests that the U.S. conduct R&D for solar technology, designed to make solar more cost-effective.[141] The U.S. has done exactly that. Solar and wind have become more cost-effective and have been implemented in greater quantities over time by market participants. In 2015 and 2016, roughly two-thirds of the new installed electricity generation capacity was wind or solar.[142]

143. The EPA Study also suggests that the U.S. expand use of natural gas as a substitute for coal in generating electricity.[143] That is exactly what has been happening over the last decade and has contributed importantly to continuing decarbonization of the U.S. energy supply.[144]

144. The EPA study further suggests as an option that the U.S. continue to promote nuclear power as a clean energy alternative.[145] The federal government has done just that, continuing to fund R&D and a broad range of programs to promote nuclear power.[146]

145. As another example, Plaintiffs' expert Professor Eric Rignot recommends that the U.S. Defendants be ordered to "take strong steps to increase the U.S. capacity for carbon sequestration."[147] This option is already being developed through the DOE.[148] Carbon capture and storage (carbon capture and sequestration) technologies have been successfully implemented in some limited applications, but whether such technologies can be scaled effectively is open to

[140] "Policy Options For Stabilizing Global Climate," U.S. Environmental Protection Agency Report, 1990, pp. V76–77.
[141] "Policy Options For Stabilizing Global Climate," U.S. Environmental Protection Agency Report, 1990, p. 29.
[142] See Figure 7.
[143] "Policy Options For Stabilizing Global Climate," U.S. Environmental Protection Agency Report, 1990, p. 34.
[144] See Figure 6.
[145] "Policy Options For Stabilizing Global Climate," U.S. Environmental Protection Agency Report, 1990, p. 31.
[146] See Section VII.B.
[147] Expert Report of Eric Rignot, Ph.D., filed April 11, 2018 ("Rignot Report"), p. 19.
[148] "Carbon Storage Research," *Department of Energy*, https://www.energy.gov/fe/science-innovation/carbon-capture-and-storage-research, accessed August 3, 2018.

question.[149] As discussed above, the DOE has multiple programs to promote carbon capture and sequestration and has significantly advanced the knowledge base in order to increase the U.S. capacity for carbon sequestration.

IX. Policy Initiatives Demanded by Plaintiffs' Experts Have Been Considered, Debated, and Rejected by Congress or Federal Administrations

146. As shown above, the federal government has taken many steps to promote energy efficiency and renewable energy. Although these approaches may not have been the policy instruments that some of Plaintiffs' experts prefer, they have been effective in reducing GHG emissions from what they would otherwise have been.[150] There are cases in which the federal government has considered and ultimately did not pursue the policies Plaintiffs suggest.

147. In particular, Professor Stiglitz states that the federal government should impose a carbon tax in order to create incentives for private firms and individuals to emit less CO_2.[151] Legislators and the executive branch agencies have proposed and debated but rejected policy incentives that would have mitigated GHGs through putting a price on carbon emissions or a tax on energy from fossil fuels, as I discuss in subsequent paragraphs.

148. In what follows, I summarize attempts by federal policy makers to use such a carbon pricing strategy, as advocated by Professor Stiglitz. The extended consideration of carbon pricing provides an example of the energy policy balancing act—either other objectives have received greater weight than environmental objectives or other instruments, such as direct regulations on energy efficiency or R&D initiatives, have been favored by federal policy makers.

149. In early 1993, the Clinton administration proposed a tax on producers, refiners, and transporters of nonrenewable energy sources, with the tax based on the amount of BTU used.

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[149] "Carbon Storage Research," *Department of Energy*, https://www.energy.gov/fe/science-innovation/carbon-capture-and-storage-research, accessed August 3, 2018.

[150] See Figures 4, 5, and 6 as well as the discussion in Section VI.

[151] I also have publicly advocated and still advocate in favor of creating incentives for private sector firms and individuals to reduce GHG emissions, through carbon pricing, either a carbon tax or a cap-and-trade system. Stiglitz Report, ¶45.

Accordingly, the tax was known as the "BTU tax."[152] President Clinton argued that the incentives associated with the tax would encourage energy conservation, reduce pollution, and lessen U.S. dependence on foreign oil,[153] and that it was the fairest and most environmentally sound way to raise revenue in order to lower the budget deficit.[154] Opponents argued that such a tax would make energy-intensive industries, such as petrochemicals, steel, and glass, less economically competitive in international markets and thereby would harm the U.S. economy.[155] Analysts believed that the BTU tax would have, on average, raised electricity prices for consumers by 30%.[156] The BTU tax, it was believed, would create incentives leading to security and environmental benefits but would have negative economic consequences. The tax was approved by the House of Representatives ("House"), but later abandoned after it did not receive a majority vote in the Senate.[157]

150. A second class of carbon pricing policy measures would create incentives to limit GHG emissions through a cap-and-trade system. This system would set an economy-wide limit, or cap, on GHG emissions each year, and the cap would decline over time. The government would issue allowances, each allowing a company to emit one ton of CO_2. Allowances could be distributed free of charge, auctioned off, or otherwise sold. Firms would be required to surrender allowances equal to the number of tons of CO_2 they emitted. Firms could buy and sell the allowances on markets, possibly futures markets, in which the price of the allowances would be determined by market forces. The price on the allowances—the carbon price—would provide

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[152] Steven Greenhouse, "Clinton's Economic Plan: The Energy Plan; Fuels Tax: Spreading the Burden," *New York Times*, February 18, 1993, https://www.nytimes.com/1993/02/18/us/clinton-s-economic-plan-the-energy-plan-fuels-tax-spreading-the-burden.html, accessed August 3, 2018.

[153] David S. Hilzenrath, "Miscalculations, Lobby Effort Doomed BTU Tax Plan," *Washington Post*, June 11, 1993, https://www.washingtonpost.com/archive/business/1993/06/11/miscalculations-lobby-effort-doomed-btu-tax-plan/d756dac3-b2d0-46a4-8693-79f6f8f881d2/?noredirect=on&utm_term=.0283a25da88e, accessed August 3, 2018.

[154] David Rosenbaum, "Clinton Backs Off Plan for New Tax on Heat in Fuels," *New York Times*, June 9, 1993, https://www.nytimes.com/1993/06/09/us/clinton-backs-off-plan-for-new-tax-on-heat-in-fuels.html, accessed August 3, 2018.

[155] David Rosenbaum, "Clinton Backs Off Plan for New Tax on Heat in Fuels," *New York Times*, June 9, 1993, https://www.nytimes.com/1993/06/09/us/clinton-backs-off-plan-for-new-tax-on-heat-in-fuels.html, accessed August 3, 2018.

[156] Ted Nordhous and Michael Shellenberger, "Getting Real on Climate Change," *The American Prospect*, December 2008, https://thebreakthrough.org/blog/PDF/Getting%20Real%20on%20Climate%20Change.pdf.

[157] David S. Hilzenrath, "Miscalculations, Lobby Effort Doomed BTU Tax Plan," *Washington Post*, June 11, 1993, https://www.washingtonpost.com/archive/business/1993/06/11/miscalculations-lobby-effort-doomed-btu-tax-plan/d756dac3-b2d0-46a4-8693-79f6f8f881d2/?noredirect=on&utm_term=.0283a25da88e, accessed August 3, 2018.

companies incentives to reduce emissions whenever the cost of reduction would be lower than the price of allowances.

151. Cap-and-trade systems were first proposed legislatively by the Climate Stewardship Act of 2003 (McCain-Lieberman), which failed to pass the Senate.[158] The Bush administration argued that the bill would lead to job losses and that "the administration instead is promoting fuel and appliance efficiency standards and building codes that will conserve energy."[159] In fact, as discussed above, the administration was taking such steps. Later McCain-Lieberman bills would also fail to pass the Senate when they were reintroduced in 2005 and 2007.[160] More recently, the House passed the American Clean Energy and Security Act of 2009, but the bill failed to pass the Senate, with statements of economic concerns.[161] The ongoing recession was said to add to many Americans' long-term economic uncertainty or fear, making it much more difficult to pass clean energy and global warming legislation.[162] Economic issues, especially issues of impacts on particular industries and regions of the country, were given high priority by the administration and Congress.

152. Recently, two bills were introduced in the House in 2015. H.R. 972 was a cap-and-trade system that included a provision that the revenues be returned as dividends to taxpayers.[163] H.R. 1027 was a "cap-and-dividend" system, essentially a cap-and-trade system in which all allowances would be auctioned and in which all auction revenues would be returned to each U.S. resident with a valid social security number.[164] Neither of these bills went any further than their referrals to the Subcommittee on Energy and Power.

153. A third class of policy measures to limit GHG emissions is carbon taxes. Such plans would typically set a tax on the production or first importation of products whose use would release CO_2 into the atmosphere. The tax would be proportional to the carbon content of the

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[158] Senate Resolution 139, 108th Congress, 2003.
[159] Juliet Ellperin, "U.S. Firms Look Ahead to Emissions Cuts Overseas," *Washington Post*, October 3, 2004, http://www.washingtonpost.com/wp-dyn/articles/A2936-2004Oct2.html, accessed August 3, 2018.
[160] Senate Resolution 1151, 109th Congress, 2005; see also Senate Resolution 280, 110th Congress, 2007.
[161] Bryan Walsh, "Why the Climate Bill Died," *Time*, July 26, 2010, http://science.time.com/2010/07/26/why-the-climate-bill-died/, accessed August 3, 2018.
[162] Daniel J. Weiss, "Anatomy of a Senate Climate Bill Death," *Center for American Progress*, October 12, 2010, available at https://www.americanprogress.org/issues/green/news/2010/10/12/8569/anatomy-of-a-senate-climate-bill-death, accessed August 3, 2018.
[163] House Resolution 972, 114th Congress, 2015.
[164] House Resolution 1027, 114th Congress, 2015.

product. Typically, the products included would be coal, petroleum, or natural gas. The revenues collected by the tax could be added to the general fund, returned to taxpayers ("recycled"), or could allow reductions in other taxes.

154. The first bill proposing a carbon tax was H.R. 4805, authored by Representative Fortney Pete Stark in 1990. He made similar proposals in 1991 (H.R. 1086) and 1993 (H.R. 804). Opponents offered H.R. 438, to express the sense of the House that no such carbon taxes should be imposed. All of the bills were referred to the House Ways and Means committee. They made it no further in the legislative process.[165]

155. Carbon tax bills continued to be introduced periodically into Congress, but none received enough support to become law. Recent bills were introduced in the Senate and in the House in 2015. H.R. 309, H.R. 2202, and H.R. 4283 were introduced in the House and referred to various committees. S.1548 and S.2399 were introduced in the Senate and referred to the Committee on Finance. None of these bills received enough support to advance further.[166]

156. Such carbon tax proposals are still (as of July 2018) being considered. Press reports assert that "Rep. Carlos Curbelo (R-Fla.) is preparing to introduce legislation that would pause federal regulations on climate change in exchange for an escalating tax on carbon emissions…." The article goes on to say: "…GOP opponents are already targeting it as anathema to Republican principles on economic growth. The House Rules Committee is meeting today on whether to allow a vote on a resolution that calls carbon taxes 'detrimental' to the economy."[167] The proposal and the opposition again show the conflict between economic objectives and environmental objectives.[168]

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[165] House Resolution 4805, 101st Congress, 1990; House Resolution 1086, 102nd Congress, 1991; House Resolution 804, 103rd Congress, 1993; "Know the Legislation," *Price on Carbon*, https://priceoncarbon.org/business-society/history-of-federal-legislation/, accessed August 3, 2018.

[166] House Resolution 309, 114th Congress, 2015; House Resolution 2202, 114th Congress, 2015; House Resolution 4283, 114th Congress, 2015; Senate Resolution 1548, 114th Congress, 2015; Senate Resolution 2399, 114th Congress, 2015.

[167] Zack Colman and Nick Sobczyk, "House Republican Will Introduce $23 Carbon Tax Next Week," *eenews.net*, July 17, 2018, https://www.eenews.net/climatewire/2018/07/17/stories/1060089315, accessed August 6, 2018.

[168] A much more complete discussion of cap-and-trade or carbon tax is the web site: "Price on Carbon," https://priceoncarbon.org/. In particular, the web page "Know the Legislation," provides a much more complete discussion of legislative attempts to put a price on carbon through a cap-or-trade system or a carbon tax. See "Know the Legislation," *Price on Carbon*, https://priceoncarbon.org/business-society/history-of-federal-legislation/, accessed August 3, 2018.

157. A review of the past legislative history makes it clear that Congress has actively considered these alternative proposals to place a tax on carbon and has done so many times since 1990. Many bills were introduced and considered in committees. Some were voted on the floor of the House or Senate. But none received the required votes to be passed by both the House and the Senate. The class of policy instruments advocated by Professor Stiglitz has been considered many times by federal policy makers and has, so far, been rejected.

158. The potential consequences of these proposals have been discussed in the economic literature and presumably have been understood by members of Congress and past administrations. The U.S. Congress has not chosen to make the changes proposed by Plaintiffs. Plaintiffs' experts are thus asking the Court to override the trade-offs that have been made deliberately in the legislative processes.

X. There Is an Important Economic Distinction between the Federal Government's Direct Emissions and the Federal Government's Role and Potential Role as Regulator of Third-Party Emissions

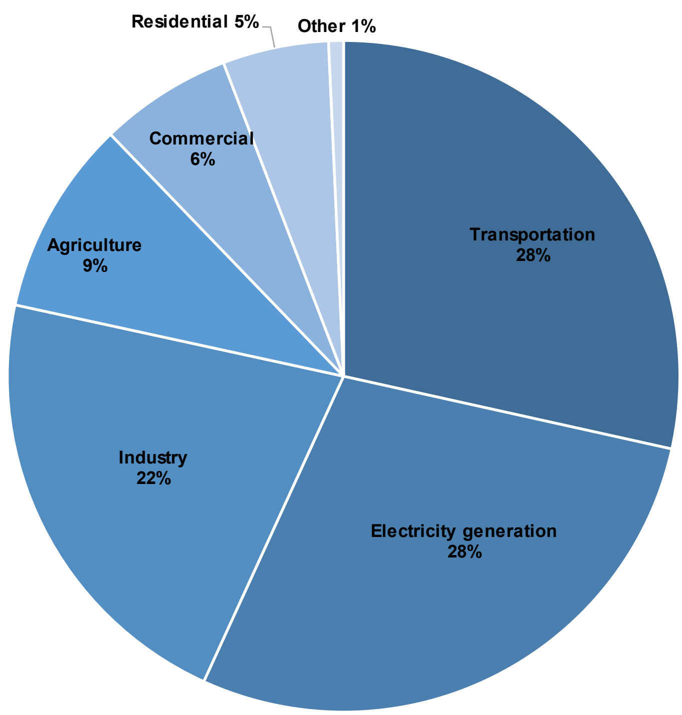
159. Plaintiffs assert that the federal government has not caused the U.S. economy to reduce emissions of GHG as much as the federal government should have.[169] There is an important economic distinction to make between the direct emissions of the federal government and the federal government's role in regulating the emissions of third parties such as companies, individuals, and state and local governments. The federal government directly controls its own emissions, but does not control the conduct of third parties. As a result, the federal government

[169] Complaint, ¶98, Hansen Report, pp. 3–4, and Speth Declaration ¶10.

must rely on either command-and-control mandates or a system of regulations that create incentives to induce third parties to engage in the conduct it desires.

Figure 8. Sources of Greenhouse Gas Emissions in the U.S.

2016



Source: U.S. Environmental Protection Agency, 2018, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2016."

Note: Other refers to "U.S. Territories" in the EPA dataset.

160. The vast majority of GHG emissions in the U.S. come from activities of private sector firms, individual residents of the U.S., and state and local governments from consumption and production activities, such as driving cars and trucks, growing and transporting food, lighting and heating their homes and offices, manufacturing goods and services.[170] Figure 8 shows the 2016 estimate of these various sources. Importantly, only a very small fraction of these sources is directly controlled by the federal government. For example, electricity generation is primarily regulated by states, with limited direct oversight by the federal government. Transportation is dominantly cars and trucks purchased and driven by individuals or businesses. The federal

[170] As I discuss in Section XI, the direct emissions of the Federal government are a small proportion of U.S. emissions.

government has passed laws (CAFE standards) creating minimum fuel economy standards, but does not regulate how much anyone drives or rides in a vehicle. Most aircraft passenger-miles are provided by private sector airlines.

161. The federal government does not directly control the actions of these third parties. Therefore, reducing emissions by third parties would require providing incentives for third parties to choose actions that emit less. From an economics perspective, even banning emissions (a form of direct mandate) can be viewed as providing a (dis)incentive. Given the (dis)incentives of choosing certain actions, private entities will weigh the benefits of emitting against the potential costs. Costs under an emissions ban would include the penalties associated with emitting taking into account the likelihood of getting caught. Bans come with their own costs such as potentially generating black markets for the banned goods and requiring enforcement by the government. Before instituting a ban (or other form of (dis)incentive), it is important to consider the costs and benefits of the intervention.

162. As an example, I examine some of the economic considerations associated with fossil fuel production, distinguishing between the direct decisions of the federal government and the federal government's role in regulating third parties.

163. Plaintiffs state that the federal government has allowed "excessive" production of fossil fuels from federal lands[171] and that the federal government has allowed, permitted, and subsidized production of fossil fuels in the U.S. by private sector firms and individuals on lands owned by private parties.[172] Although Plaintiffs emphasize the negative externalities, judgments about the appropriate amount of fossil fuel production depends on a comparison of the benefits and costs. Plaintiffs appear to have not examined this balance.

164. There is an economic benefit to the U.S. of producing these natural resources. First, these fossil fuels are used by private sector firms, individual residents of the U.S., and state and local governments, among others, who value use of the fossil fuels. If these fuels are not available, these users would derive the value from fossil fuels produced elsewhere or would not

[171] Complaint, Section II. B. Note that the majority of each of the fossil fuels was not produced on federal lands. In 2016, 24% of the crude oil was produced on federal lands, 14% of the natural gas, and 40% of the coal. See National Resources Revenue Data, U.S. Department of the Interior, https://revenuedata.doi.gov/explore/, accessed August 3, 2018.
[172] Complaint ¶110–112.

derive that value at all. For example, users would either need to substitute towards more expensive or inconvenient forms of transportation, manufacturing, space heating, etc. or to forgo these end uses of energy altogether. Second, production of these fossil fuels provides jobs, particularly in some regions facing only limited employment options. Third, production of these fossil fuels provides profit for the producing firms. Fourth, production of these fossil fuels provides revenues to the federal government in the form of bonus bids, royalties, and taxes. Finally, production of fossil fuels decreases energy imports into the U.S. and thus reduces U.S. vulnerability to energy supply disruptions, thereby enhancing national security.

165. Subtracting from the economic benefits are the economic costs, particularly the environmental externalities associated with fossil fuel production and use.

166. Stopping production would have negative consequences, including economic losses to regions of the country, individuals, and industries, and a loss of revenues captured by the government. Reducing crude oil production could be expected to increase the price of crude oil and gasoline, leading to a redistribution of wealth from both the developing and developed oil-importing countries to the oil exporting countries (and in many cases, to their rulers.) Reducing natural gas production could be expected to increase the price of electricity. These cost increases would have negative income impacts on consumers of gasoline, electricity, and other energy. Stopping production would lead to job losses, concentrated in energy producing areas of the U.S., some of which have only limited employment options. It would lead to increased imports of energy with the resulting reductions in national security. Stopping production implies that the federal government would have to either increase taxes to cover the losses, reduce the provision of federally provided services, or increase the national debt.

167. These consequences have been valued differently by different segments of the U.S. population. Federal administrations have had the opportunity to expand or contract the federal leasing, based on their judgments of the array of consequences. Congress has the opportunity of influencing the nature and extent of leasing. But given the very negative consequences of halting production, I have not found it surprising that there has been a consistent policy of using the natural resources, including for the production of fossil fuels.

168. Plaintiffs ask that the Court "order Defendants to cease their permitting, authorizing, and subsidizing of fossil fuels…."[173] Plaintiffs have made this recommendation but apparently have not laid out the negative consequences, including economic losses to regions of the country, individuals, and industries, the loss of revenues captured by the government, and the national security reductions.

XI. Plaintiffs and Their Experts Fail to Establish that the Acts of the Federal Government Caused Their Alleged Injuries

169. In this section I turn from U.S. energy policy and the merits of Plaintiffs' allegations regarding U.S. energy policy to Plaintiffs' theory of harm.

170. Plaintiffs allege that their injuries were caused by three elements of Defendants' alleged conduct (the "conduct at issue"), each of which caused GHG emissions to increase:

(i) the U.S. government's consumption of fossil fuels;

(ii) Defendants' affirmative regulatory acts (e.g., tax subsidies for fossil fuel production, permits for extraction of fossil fuels from public lands, and other measures), which increased the supply of fossil fuels available for purchase and consumption by entities other than the federal government; and

(iii) Defendants' alleged failure to develop policies to eliminate the use of fossil fuels and mitigate GHG emissions by entities other than the federal government.

171. I show in this section that Plaintiffs fail to establish a causal link from the conduct at issue to the injuries they allege. Plaintiffs attribute their injuries to the conduct at issue, but ignore the fact that at least 96% of cumulative global CO_2 emissions since 1990 — the root cause of rising atmospheric CO_2 concentrations and climate change effects that purportedly lead to Plaintiffs' alleged injuries — are associated with fossil fuel consumption unrelated to the conduct at issue.[174]

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[173] Complaint, ¶12.

[174] For purposes of rebuttal, I assume *arguendo* that the conduct at issue began as of 1990. Global CO_2 concentration as of 1990 was approximately 350 ppm, the level that Plaintiffs propose in their request for relief. See Complaint, ¶259. Further, in terms of the expectation that the government should have known and should have made policy based on its knowledge, 1990 is a reasonable date. Professor Hansen published his seminal climate

a. Countries other than the U.S. accounted for 79% of cumulative energy-related CO_2 emissions from 1990 to 2015.[175]

b. The remaining 21% of global CO_2 emissions during that period occurred in the United States. A large majority of these emissions were not caused by the conduct at issue.

c. CO_2 emissions caused directly by the government through its consumption of fossil fuels comprise approximately 0.25% of global CO_2 emissions. Thus approximately 99.75% of global energy-related CO_2 emissions were caused by countries other than the United States, or by entities in the United States other than the Federal government.

d. I estimate that CO_2 emissions caused by all of the conduct at issue, including emissions allegedly caused directly by Defendants, emissions allegedly caused by Defendants' affirmative policy acts, and emissions allegedly caused by Defendants' alleged failure to act, comprise no more than 4% of global emissions. Note that this figure includes emissions from the actions of entities in the U.S. other than the federal government, including private sector firms, individual residents of the U.S., and state and local governments. Thus at least 96% of global emissions were caused by (i) countries other than the U.S., or (ii) fossil fuel consumption by entities other than the federal government that would have occurred absent Defendants' conduct at issue.

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change paper in 1981 and testified before the U.S. Senate in 1988 and 1989, and the EPA published a study of climate stabilization options ("Policy Options for Stabilizing Global Climate") in 1990. See Hansen Report, pp. 12-13, 16 and Complaint, ¶3. Plaintiffs claim that a 1965 report published by the White House ("Restoring the Quality of Our Environment") is a further example of the "extensive knowledge Defendants have had about the dangers they caused to present and future generations." See Complaint, ¶6. However, the White House Report also conveys a great deal of uncertainty and does not appear to be a sufficiently strong foundation to dictate energy policy. For example, the report states that "the increase in atmospheric CO_2 … may be sufficient to produce measurable changes in climate," but that "at present it is impossible to predict these effects quantitatively," and that "even today, we cannot make a useful prediction concerning the magnitude or nature of the possible climatic effects." See "Restoring the Quality of Our Environment," The White House, 1965, pp. 114, 126, 127.

[175] U.S. Energy Information Administration, International Energy Statistics. Plaintiffs state that "[b]etween 1751 and 2014, the United States has been responsible for emitting 25.5% of the world's cumulative CO_2 emissions." Complaint, ¶151. Defendants have stated that "from 1850 to 2012, CO_2 emissions from sources within the United States (including from land use) comprised more than 25 percent of cumulative global CO_2 emissions." See Answer, ¶151.

172. Finally, I conclude that Plaintiffs fail to establish a causal link between their alleged injuries and climate change effects allegedly caused *by the conduct at issue*. I conclude that factors other than the conduct at issue are the primary causes of the climate change effects that the Plaintiffs allege to have caused injuries.

A. Plaintiffs and Their Experts Fail to Establish Causation

173. Plaintiffs and their experts appear to attribute their alleged injuries solely and exclusively to the alleged conduct at issue. However, many factors other than the conduct at issue have contributed to a higher atmospheric CO_2 concentration and consequent climate change effects. Given this, Plaintiffs' implicit argument that their injuries are attributable primarily to U.S. emissions is incorrect. Plaintiffs and their experts fail to account for these factors and isolate the incremental contribution of the conduct at issue to Plaintiffs' alleged injuries.

174. Plaintiffs state that:

a. The conduct at issue caused an increase in the supply and consumption of fossil fuels in the U.S. and an increase in U.S. CO_2 emissions.[176]

b. Increased U.S. CO_2 emissions in turn caused an increase in the atmospheric concentration of CO_2.[177]

c. Higher CO_2 concentration in turn caused climate change effects, including higher temperatures, changes in precipitation patterns and amounts, an increase in the likelihood of extreme weather events, and other changes in climate.[178]

d. Climate change effects in turn allegedly caused Plaintiffs' injuries (e.g. health effects, psychological effects, loss of recreational enjoyment, property damage, etc.).[179]

175. Based on Defendants' Answer and for purposes of this litigation, I understand that the links in the middle of the chain (i.e., (a)-(c) above) are not contested.[180] However, items (a)-(c)

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[176] Complaint, ¶¶151–153.
[177] Complaint, ¶98.
[178] Complaint, ¶¶131, 220.
[179] Complaint, ¶¶16–97.
[180] Answer, ¶1.

alone are not sufficient to establish that the conduct at issue was the sole or primary cause of Plaintiffs' alleged injuries. Plaintiffs and their experts do not present any analysis that controls for the impact of emissions from sources other than the federal government. Thus even if they can establish that global climate change caused their injuries, they have not presented any analysis to show that Defendants' emissions (or emissions caused by Defendants' conduct at issue) caused Plaintiffs' alleged injuries.

176. Plaintiffs and their experts fail to state what CO_2 concentrations and U.S. CO_2 emissions would have been absent the conduct at issue. Indeed, Plaintiffs do not say when the conduct at issue first began, which makes it impossible to determine the counterfactual level of emissions and CO_2 concentration.[181]

177. Further, they fail to state the amount (if any) by which the "unusually dangerous risks," "imminent dangers," and other injuries alleged in the complaint increased as a result of changes in CO_2 concentration and consequent climate change effects. These are glaring omissions.

B. Plaintiffs' Experts Fail to Identify the Incremental Impact of the Conduct at Issue on Cumulative CO_2 Emissions and CO_2 Concentration

178. The U.S. has contributed 21% of cumulative global energy-related CO_2 emissions since 1990.[182] It follows that 79% of global energy-related CO_2 emissions since 1990 are attributable to countries other than the U.S. However, Plaintiffs fail to account for this fact. If approximately 79% of the change in CO_2 concentration since 1990 is attributable to sources other than the U.S., then Plaintiffs' apparent belief that their injuries are attributable solely to the conduct at issue is wrong on its face.

179. Further, Plaintiffs fail to identify the portion of U. S. territorial emissions (i.e., all energy-related emissions generated in the United States) that are specifically attributable to the conduct at issue. I show in the following sections that a large majority of U.S. territorial emissions were unrelated to the conduct at issue, whether construed narrowly as emissions from Defendants' consumption of fossil fuels, or broadly as emissions generated by entities other than the government as a result of Defendants' conduct at issue. Emissions from Defendants' direct

[181] For purposes of rebuttal, I assume *arguendo* that the conduct at issue began as of 1990.
[182] U.S. Energy Information Administration, International Energy Statistics.

consumption of fossil fuels were a very small part of total U.S. emissions, and emissions caused by Defendants' affirmative policy acts (e.g., subsidies) were small as well.

1. Defendants' Direct Consumption of Fossil Fuels

180. Although the U.S. government is a large consumer of energy relative to other economic actors in the U.S.,[183] it represents only a small fraction of U.S. territorial emissions, and therefore a very small fraction of global emissions, hence its contribution to CO_2 concentration (which depends on *global* emissions) is very small.[184]

181. EIA data show that the federal government accounted for 1.2% of total U.S. energy consumption from 1990 to 2015.[185] Assuming that the carbon intensity of the government's energy consumption is the same as the carbon intensity of the U.S. economy as a whole, it follows that the federal government accounted for 1.2% of U.S. energy-related CO_2 emissions from 1990 to 2015 and 0.25% of global energy-related CO_2 emissions from 1990 to 2015.[186]

182. Thus 99.75% of all energy-related global CO_2 emissions from 1990 to 2015 was caused by entities other than the federal government.

[183] The government consumes energy to operate more than 350,000 buildings and power more than 600,000 vehicles. See "Government Energy Management," Office of Energy Efficiency and Renewable Energy, https://www.energy.gov/eere/efficiency/government-energy-management, accessed August 3, 2018. The Department of Defense is the largest energy consumer among government agencies, except for the use of gasoline by the U.S. Postal Service, which accounted for 40% of the U.S. government's total gasoline consumption. See "U.S. federal government energy costs at lowest point since fiscal year 2004," *U.S. Energy Information Administration*, https://www.eia.gov/todayinenergy/detail.php?id=33152, accessed August 3, 2018.

[184] Note also that the federal activities that emit GHGs have important value to the fundamental objectives– economic welfare, national security, and environmental protection. Shutting these activities down would lead to severe negative consequences, unless these activities were conducted by private sector firms. In that case, the greenhouse gas emissions could be expected to be as great as they are now. And in some cases, such as national defense, it is very unlikely that the function could be conducted nearly as effectively if it were not the responsibility of the Federal government.

[185] U.S. Energy Information Administration, "July 2018 Monthly Energy Review," Table 2.1 Energy Consumption by Sector, Table 2.7 U.S. government energy consumption by agency, fiscal years.

[186] Approximately 0.21 (U.S. share of global energy-related CO_2 emissions from 1990 to 2015) * 0.012 (U.S. federal government's share of U.S. energy-related CO_2 emissions from 1990 to 2015) = 0.0025 (U.S. federal government's share of global energy-related CO_2 emissions).

2. Defendants' Affirmative Policy Acts

183. As of 2015, the majority of U.S. fossil fuel production was on private land and was therefore unaffected by government permitting policies for public lands.[187] Moreover, because the U.S. is a net importer of fossil fuels,[188] sources other than U.S. public lands account for an even larger proportion of U.S. fossil fuel *consumption*.

184. As for subsidies, which affect production incentives on private and public land, academic research has shown that while subsidies may induce fossil fuel production from otherwise unprofitable sources, the incremental impact is small and decreases as the price of oil increases.[189] Moreover, the subsidies themselves are available only for small, independent producers; integrated suppliers are not eligible.[190] Further, the aggregate subsidies are small: as explained previously, the average subsidy paid to fossil fuel producers was approximately $0.02 per gallon of gasoline. By comparison, the average tax on a gallon of gasoline from 1990 to 2015 was approximately $0.53 per gallon, or more than twenty times the size of subsidies.[191]

185. Further, the subsidies at issue would likely have a negligible impact on global production and consumption of fossil fuels and GHG emissions because changes to domestic fossil fuel production would likely be offset by changes in world production, and because demand for fossil

[187] As of 2016, less than half of fossil fuel production in the U.S. was on federal lands. Public land accounted for 14% of U.S. natural gas production, 24% of U.S. crude oil production, and 40% of U.S. coal production. See National Resources Revenue Data, U.S. Department of the Interior, https://revenuedata.doi.gov/explore/, accessed August 3, 2018.

[188] U.S. Energy Information Administration, "May 2018 Monthly Energy Review," Table 1.4b Primary Energy Exports by Source and Total Net Imports.

[189] For example, Jewell et al. (2018) find that "removing fossil fuel subsidies would have an unexpectedly small impact on global energy demand and CO_2 emissions and would not increase renewable energy use by 2030." See Jessica Jewell et al., "Limited Emission Reductions from Fuel Subsidy Removal Except in Energy-Exporting Regions," *Nature* 554, 2018, pp. 229. Erickson et al. (2017) find that tax preferences and direct subsidies can push oil production from being unprofitable to profitable. Their result depends on oil prices. If oil prices increase to $75 per barrel, the impact of subsidies will be limited. See Peter Erickson et al., "Effect of Subsidies to Fossil Fuel Companies on United States Crude Oil Production," *Nature Energy* 2, 2017, pp. 891–898.

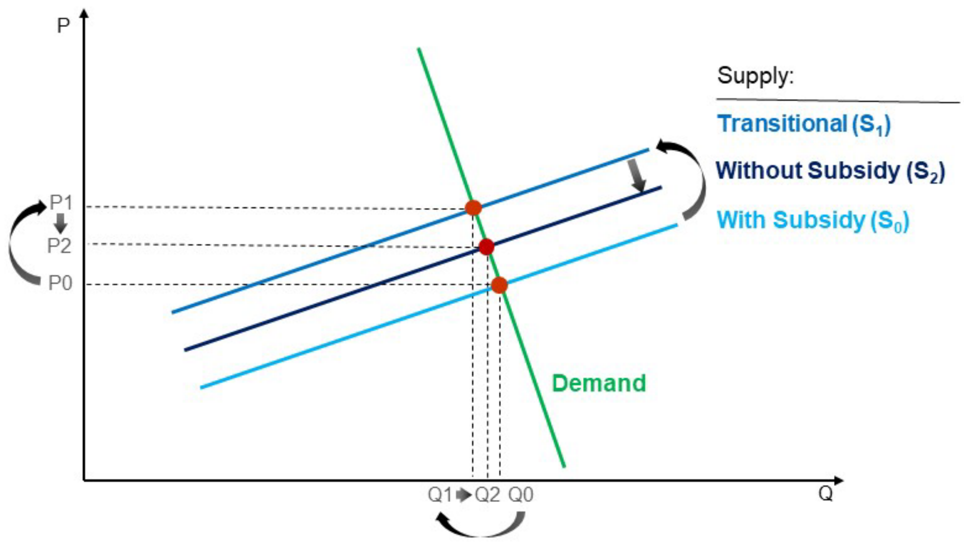
[190] David Blackmon, "Oil And Gas Tax Provisions Are Not Subsidies For 'Big Oil'," January 2, 2013, *Forbes*, https://www.forbes.com/sites/davidblackmon/2013/01/02/oil-gas-tax-provisions-are-not-subsidies-for-big-oil/#6bd8d0ca52e8, accessed August 12, 2018.

[191] As of January 1, 2018, the federal gasoline tax was $0.18 per gallon, and average state tax was $0.28. From 1990 to 2015, the average combined federal and state gasoline tax was approximately $0.53 per gallon. See "How much tax do we pay on a gallon of gasoline and a gallon of diesel fuel?" U.S. Energy Information Administration, https://www.eia.gov/tools/faqs/faq.php?id=10&t=10, accessed August 11, 2018. See also "Highway Statistics 2015," *U.S. Department of Transportation*, Table MF–205 State Motor-Fuel Tax Rates, Table FE–101A Federal excise tax rates on motor fuels and lubricating. oil. See also "Highway Statistics 2000," *U.S. Department of Transportation*, Table MF–1, State Motor-Fuel Tax Rates, 1985–2000.

fuels is relatively inelastic (i.e., not sensitive to price changes).[192] Figure 9 shows the impact on fossil-fuel consumption if the U.S. were to remove subsidies. The bottom fossil fuel supply line shows the quantity of fossil fuels that producers would provide at a given price with subsidies in place from the federal government. Removing the subsidies would reduce U.S. fossil fuel output and shift global supply to the transitional supply line, which exhibits a higher price required to produce a given quantity of fossil fuels than the original supply line. The increase in price, however, would induce additional production from the rest of the world and partially offset the reduction in supply from the U.S. This is depicted in the figure by the movement from the transitional supply line to the final supply line with no U.S. subsidies. Thus the overall quantity of fossil fuel production and consumption is relatively small. Furthermore, because demand is inelastic (the line representing demand is almost vertical), movements in the supply curve do not translate into large changes in the quantity of fossil-fuel production and consumption.

[192] John C.B. Cooper, "Price Elasticity of Demand for Crude Oil: Estimates for 23 Countries," *OPEC Review* 27, no. 1, 2003, pp. 1 ("The estimates so obtained confirm that the demand for crude oil internationally is highly insensitive to changes in price.").

Figure 9. Global Fossil Fuel Market Response to Removal of U.S. Subsidies



3. Defendants' Alleged Failure to Develop Policies to Mitigate GHG Emissions by Entities Other Than the Federal Government.

186. Plaintiffs and their experts offer no analysis to link the failure to develop policies to the impacts on GHG emissions. Thus I conduct two back-of-the-envelope calculations to distinguish between GHG emissions caused by the conduct at issue, and emissions not caused by the conduct at issue.

187. Suppose the U.S. had ceased policies facilitating fossil fuel supply and consumption, and acted to encourage the development of clean energy, and assume for illustration that these hypothetical policy changes could have reduced past U.S. energy-related emissions by 20%. Then global emissions would have been about 4% lower.[193] If all emissions directly attributable to the federal government were halted, that would add an additional 0.25%. Thus approximately 96% of global emissions are attributable to sources other than the conduct at issue: 79% of

[193] This takes U.S. emissions to have been 21% of historical global energy-related CO_2 emissions, energy use to be approximately 95% of world CO_2 emissions, and emissions from energy uses to be reduced by 20%. Multiplying these three factors gives 3.99% reduction.

global past emissions are attributable to other countries, 17% are attributable to remaining emissions by non-federal U.S. entities, and only 4% can be attributed to the policies and direct conduct of the federal government.

188. Second, for discussion, I take the extreme assumption that somehow the U.S. was able to eliminate all fossil fuel production and consumption from 1990 onward. This extreme assumption would have been impossible, but it allows some observations.

189. Because the U.S. was a net importer of fossil fuels as of 1990, if the U.S. had ceased both production and consumption of fossil fuels in 1990, aggregate global demand would have contracted by a larger amount than aggregate global supply, equilibrium prices for fossil fuels would have fallen as a result, rest-of-world fossil fuel consumption would have increased in turn by a relatively small amount, and rest of the world production would increase approximately making up for the reduction in net imports to the United States. Thus, global fossil fuel consumption and production would have declined, but by an amount somewhat smaller than the decrease in the U.S. fossil fuel consumption.

190. If nothing else happened in this hypothetical scenario, the global emissions from 1990 until now would have fallen by 21%. The global emissions would still have been 79% of their actual level. However, the hypothetical scenario likely would have displaced energy-intensive industries from the U.S. to other locations in which consumption of fossil fuels remained permissible. In that case, rest-of-world fossil fuel consumption and CO_2 emissions would likely have increased due to displacement of these industries. As a result, rest-of-world CO_2 emissions would have increased and global emissions would have decreased by less than the 21%.[194] In this hypothetical scenario, more than 79% of global emissions would still be attributable to sources other than the United States.

191. If we postulated a less severe, but still hypothetical scenario, in which beginning in 1990, the U.S. production and consumption of fossil fuels were cut in half from their actual levels, then more than 90% of global emissions would still be attributable to sources other than the United

[194] See Sweeney, p. 116 ("Structural shifts are particularly significant for the industrial sector because of the movement of manufacturing to China.). See also Sweeney, pp. 116–117, fn. 3 ("This point has particular relevance for examining global climate change issues. If the particularly carbon-intensive products are manufactured in China and exported to the United States, then although the carbon emissions in the United States decrease, the U.S. decreases are matched by roughly equivalent Chinese increases in emissions.").

States.[195] However, I hasten to add, that such a scenario could not have been accomplished by the federal government.

192. I understand that Defendants' expert Professor Weyant has carried out a more formal counterfactual analysis, and likewise concludes that the incremental contribution of the conduct at issue to changes in CO_2 concentration and Plaintiffs' alleged injuries was quite small. Using climate modeling software, Professor Weyant computes CO_2 concentrations assuming that (i) U.S. CO_2 emissions fell by 25% after 1990, and (ii) U.S. CO_2 emissions were zero (i.e., declined by 100%) after 1990. These two scenarios correspond to the assumption that the conduct at issue caused, respectively, 25% and 100% of U.S. CO_2 emissions.

193. The first scenario likely overstates the incremental contribution of all the conduct at issue to U.S. CO_2 emissions, and the second scenario corresponds to my hypothetical scenario. Actual CO_2 concentrations increased by 13% from 1990 to 2015.[196] Professor Weyant finds that CO_2 concentrations would have increased by 12% had the U.S. reduced its CO_2 emissions by 25% as of 1990, and by 10% had the U.S. eliminated its CO_2 emissions as of 1990. These results demonstrate that a large majority of the changes in CO_2 concentration since 1990 are attributable to causal factors other than the conduct at issue.

194. Further, simple economic analysis suggests that in the rest of the world, fossil fuel consumption and CO_2 emissions would have increased by a small amount in response to the U.S.'s hypothetical conduct of eliminating CO_2 emissions.[197] Global CO_2 emissions therefore would not have decreased by the amount of the reduction in the U.S. emissions, hence the change in CO_2 concentration would have been smaller than the 3 percentage point difference noted above, for the reasons discussed above.

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[195] This takes U.S. emissions to have been 21% of historical global energy-related CO_2 emissions, energy use to be approximately 95% of world CO_2 emissions, and emissions from energy uses to be reduced by 50%. Multiplying these three factors and adding direct federal emissions share of 0.25% gives 10.225% reduction.

[196] CO_2 concentration was 354 ppm in 1990 and 399 ppm in 2015. Data from National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division, ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_gl.txt, accessed August 3, 2018.

[197] The climate change literature recognizes this general economic principle. See, e.g., Christoph Böhringer et al., "Introduction to the EMF 29 Special Issue on the Role of Border Carbon Adjustment in Unilateral Climate Policy," *Energy Economics* 34, sup. 2, 2013, pp. S95–S96.

C. Plaintiffs Fail to Establish a Causal Link Between Their Alleged Injuries and Climate Change Effects Caused *by the Conduct at Issue*

195. I demonstrated in the previous section that, except in hypothetical scenarios, substantially all (96%) of cumulative CO_2 emissions since 1990 are attributable to factors other than the conduct at issue, namely emissions from other countries (79%) and emissions from entities within the U.S. other than the federal government that would have occurred absent the alleged misconduct (17%).

196. Plaintiffs fail to control for the impact of factors other than the conduct at issue, and instead assume that the climate change effects that allegedly caused their injuries are attributable entirely to the conduct at issue.

197. But this reasoning is wrong on its face. If factors other than the conduct at issue have caused substantially all of cumulative CO_2 emissions since 1990, it follows that those factors, rather than the conduct at issue, are the primary cause of the increase in atmospheric CO_2 concentration since 1990 and, therefore, the climate change effects that the Plaintiffs' alleged to have caused their injuries.

198. Examples from the Complaint demonstrate the error in Plaintiffs' logic:

a. Plaintiffs allege that named plaintiff Kelsey Cascadia Rose Juliana has already sustained injury due to a 2015 salmon die-off caused by "record-setting heat and low water levels."[198] Plaintiffs fail to show whether the "record heat," and "low water levels," that caused the salmon die-off events would occur absent the conduct at issue. Instead, they appear to assume that absent the conduct at issue, these climate change effects and consequent injuries would not occur.

b. First, this assertion fails to show that the changes were not the result of natural variability of weather. The assertion also fails to account for the fact that absent the conduct at issue, substantially all of the increase in atmospheric CO_2 concentration since 1990 would remain, as would the resulting climate change effects.

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[198] Complaint, ¶17.

c. Plaintiffs also allege that named plaintiff Jacob Lebel and his family have been forced to invest in an irrigation system "in order to contend with the increasing drought conditions as a result of climate destabilization *caused by Defendants*."[199] Plaintiffs appear to assume that absent the conduct at issue, there would be no "increasing drought conditions," and that construction of the irrigation system would therefore not be necessary. Again, this logic fails to account for the fact that absent the conduct at issue, substantially all of the increase in atmospheric CO_2 concentration since 1990 would remain, as would the resulting climate change effects that made the Lebels' irrigation system necessary.

199. The remaining injury claims set forth in the Complaint exhibit similar errors in logic.

200. Finally, Plaintiffs ignore the benefits they may have realized as a result of the conduct at issue. Plaintiffs' injuries (if any) attributable to the conduct at issue will be overstated unless Plaintiffs also account for benefits received as a result of those acts. Plaintiffs likely benefitted from U.S. climate policies since 1990; those benefits include living in a safer nation due to national security priorities, benefitting from government and private services that relied on fossil fuels, including the U.S. armed forces. In order to accurately assess Plaintiffs' injuries (if any), all of the benefits and harms that Plaintiffs received from current policies must be considered and compared to the benefits and harms they would realize under the counterfactual climate policy scenario. Plaintiffs have not shown this more complete and balanced accounting.

XII. Plaintiffs' Experts' Proposed Transformations of the U.S. Energy System Are Not Technically or Economically Feasible

201. Plaintiffs have submitted expert reports from Professor Jacobson and Professor Williams, both of whom propose highly ambitious changes to the U.S. energy system that they claim would eliminate or dramatically reduce energy-related GHG emissions in the U.S.[200]

202. Professor Jacobson proposes a transition by 2050 from the current U.S. energy infrastructure to a "100% clean, renewable energy system for all energy sectors" based on energy

[199] Complaint, ¶32, emphasis added.
[200] Jacobson Report, p. 2; Williams, Report, p. 3.

generated exclusively from renewable sources (wind, water, and solar).[201] Professor Jacobson asserts that his proposed transition is "technically and economically feasible," that any barriers impeding the transition are "social and political,"[202] and that the unit price of electricity as of 2050 would be lower than the unit price under the conventional system in use today.[203]

203. Professor Williams concludes that a "deep decarbonization pathway" leading to a reduction of 80% in U.S. GHG emissions by 2050 is "technically feasible" using "commercially demonstrated or near-commercial technologies."[204] Professor Williams estimates the cost for a transformed energy system as of 2050 as 0.8% of 2050 GDP.[205]

204. Professor Williams concedes that this level of mitigation is not sufficient to meet the 350 ppm target set forth in Plaintiffs' demand for relief. He concludes in particular that 80% mitigation of GHGs is not sufficient to avoid "dangerous anthropogenic interference with the climate system over the long term," and that mitigation of 96% of fossil fuel CO_2 emissions world-wide is necessary in order to return the atmosphere to a safer CO_2 concentration of 350 ppm (the level adopted by Plaintiffs in their demand for relief).[206] Professor Williams states this higher level of mitigation must rely on "emerging" technologies and will require higher "unit costs," additional economic losses through early retirement of fossil fuel infrastructure, and "changes in the consumption of energy services and/or rates of consumption growth."[207]

205. Many elements of the energy system transformations proposed by Professors Jacobson and Williams are not technically feasible. Both assume the existence of technologies that are in development and, at best decades from commercial acceptance. For example, as I explain below, both assume that vehicle demand will shift entirely from gasoline-powered vehicles to electric vehicles by a given date (2030, in Professor Jacobson's case), despite the fact that existing technology is not cost-effective and has so far captured very little market share. Professor

[201] Jacobson Report, p. 2.
[202] Jacobson Report, pp. 4, 11.
[203] Jacobson Report, p. 10.
[204] Williams Report, pp. 4–5.
[205] As an aside, I note that Professor Williams and Professor Jacobson contradict each other with respect to the cost of decarbonization. Professor Jacobson promises a higher level of GHG mitigation than Professor Williams (100 percent rather than 80 percent), yet the cost of Professor Jacobson's 100 percent mitigation is lower than that of the 80 percent mitigation in Professor Williams' model.
[206] Williams Report, pp. 3, 10.
[207] Williams Report, p. 12.

Jacobson further assumes that (i) by 2040, hydrogen–and electric–powered airplanes will replace existing fossil-fuel-powered jet airplanes;[208] and (ii) underground thermal energy storage ("UTES") will replace existing heating and cooling systems for residential and commercial buildings, requiring a retrofit of almost all residential and commercial buildings in the United States. He assumes this even though the largest deployment of the technology in North America is a 52-home demonstration project in which homes were purpose-built to accommodate UTES.[209]

206. Neither Professor Jacobson nor Professor Williams provides a credible estimate of the full costs of their respective proposals. They both focus on costs of energy supply, that is, the infrastructure necessary to deliver power to users, but overlook the significant investment required for consumers or businesses to invent, develop, and/or adopt new low-carbon energy technologies. As a result, their respective proposals omit many of the massive costs that the U.S. would incur in shifting to a low-carbon energy system.

207. Even if technically feasible, the energy system transformations proposed by Professors Jacobson and Williams are not economically viable and would likely require an unprecedented level of government intervention in the economy. Professor Jacobson's and Professor Williams' proposals require implicitly: (i) major consumer behavioral change, (ii) significant costs borne by the government or directly by energy users, and (iii) leaps in technology.

208. Plaintiffs' experts' proposed energy systems would require regulatory intervention on a massive scale. Neither of Plaintiffs' experts provide a sense of the wide-ranging scope of the changes required nor do they lay out the means to accomplish the required changes. They provide no evidence that their proposals can be accomplished in the context of a market economy. Furthermore, Plaintiffs' experts fail to consider all of the ramifications of the required policies.

209. Professor Jacobson offers no discussion of the policy and regulatory measures necessary to induce firms to invent and develop these low-carbon technologies (e.g. hydrogen-powered airplanes, electric cement plants) nor to produce and market them. He offers no discussion of the

[208] Jacobson Report, pp. 6, 17.

[209] Christopher T. M. Clack et al., "Supporting Information for the Paper 'Evaluation of a Proposal for Reliable Low-Cost Grid Power with 100% Wind, Water, and Solar,'" *PNAS*, 2017, p. 5.

policy and regulatory measures necessary to induce consumers and firms to adopt low-carbon technologies (e.g., vehicles, heating systems, manufacturing processes) that are more costly than alternatives based on fossil fuels.

210. While Professor Williams addresses questions of policy in Exhibit E of his report, his analysis raises questions about the economic system that would be consistent with his proposals.

211. Both experts ignore significant economic and/or technical obstacles to their respective proposals, and simply assert, without support, that there are no such obstacles.[210] The fact is that there are numerous technical and economic barriers that would impede the adoption of their proposed energy systems. Ignoring these obstacles and ordering policy based on these proposals would not lead to the desired outcome Plaintiffs seek.

212. Plaintiffs' experts' proposed energy systems, implementation timelines, and cost estimates deviate greatly from the conclusions set forth in a large body of literature that studies the problem of decarbonization and GHG mitigation.

213. I explore each of these points in the sections that follow.

A. Several Examples Demonstrate the Technical and Economic Infeasibility of Converting Energy End Use to All-Electric or All-Hydrogen Systems

214. I demonstrate the technical and economic infeasibility by analyzing two sectors (transportation and industrial) that would be difficult if not impossible to convert to zero emissions given present technology.

215. Given these obstacles, one can infer that Professor Jacobson's and Professor Williams' proposed energy systems could become a reality only if the government abandoned free market principles throughout the economy, adopted a command-and-control approach, and mandated the adoption of the technologies proposed in their energy system, or provided massive subsidies, which would require tax increases to pay for the subsidies. Such a drastic move, however, still

[210] Jacobson Report, p. 4 ("Our research suggests that it is technologically and economically possible to electrify fully the energy infrastructures of all 50 United States and provide that electricity with 100% clean, renewable wind, water, and sunlight (WWS) at low cost, if the transition is commenced immediately."). Williams Report, p. 12 ("It is technically feasible to achieve an 80% reduction in greenhouse gas emissions below 1990 levels by 2050 in the United States, while maintaining current levels of energy services without requiring any conservation measures… I believe that a reduction in natural emissions as deep as 96% below present levels is technologically feasible given current and emerging technologies… but will not diminish basic quality of life and standards of living.").

would not guarantee success, as centrally planned economies have in general not been successful.

1. Transportation: Automobiles

216. Professors Jacobson and Williams each propose an aggressive, highly ambitious transformation of automobile transportation in the U.S. from vehicles largely powered by internal combustion engines to all-electric, plug-in hybrid electric vehicles ("PHEVs"), or hydrogen-powered vehicles, which I will refer to collectively as zero emission vehicles ("ZEVs").[211] The timeline set forth in Professor Jacobson's report requires that ZEVs comprise 100% of new vehicle sales by 2030; Professor Williams' plan sets 2040 as the deadline by which ZEVs comprise 100% of new vehicle sales.[212] Professor Jacobson does not discuss the policies necessary to facilitate this transformation. Professor Williams, on the other hand, suggests the need for "a combination of upfront cost reductions, consumer incentives, and roll-out of a convenient fueling infrastructure coordinated with the share of alternative vehicles in the [light-duty vehicle] fleet."[213] Neither Professor Williams nor Professor Jacobson offers any discussion about the cost of those policies.

217. As I explain in this section, these goals are far more aggressive than even the most ambitious state-level ZEV adoption plans currently in place in the U.S., and there is considerable doubt as to whether the states will realize their more modest goals. Technical challenges, such as the lack of infrastructure, hinders consumer adoption. Putting aside the question of whether 100% of consumers would actually purchase electric vehicles, I examine the cost of inducing consumers to do so. As a preliminary approximation, I compute the total payments that would

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[211] Although both hybrid electric vehicles ("HEVs") and plug-in hybrid electric vehicles ("PHEVs") have internal combustion engines and electric motors, the two types of vehicles differ in a few ways. HEVs use the internal combustion engine as the main power source with the electric motor as a complement, whereas PHEVs utilize the electric motor as the main power source. HEVs also generate electricity on board and result in less substantial energy savings compared to PHEVs. PHEVs in contrast use grid-supplied electricity. Both are considered electric vehicles ("EVs"). See Alex McEachern, "Hybrids: What is the Difference Between Traditional and Plug-in?" *Electric Vehicle News*, June 8, 2012, https://www.fleetcarma.com/hybrids-what-is-the-difference-between-traditional-and-plug-in/.

[212] Jacobson Expert Report, p. 17. Williams Report, Exhibit D, p. D83.

[213] Williams Report, Exhibit E, p. E70 ("Such strategies require working across industries – for example, with auto manufacturers and electric utilities – and need to be robust to changes in factors that affect consumer purchasing decisions, such as gasoline prices and interest rates.").

be required under California's current electric vehicle subsidy program if, as Professor Jacobson assumes, 100% of car buyers were to purchase electric vehicles ("EVs"). I find that subsidy payments would account for nearly a quarter of the state budget after removing the essential expenditures of education, corrections, and health and human services. Given low consumer acceptance of EVs to date, and the prohibitive costs of inducing consumers to purchase EVs rather than gasoline-powered vehicles, command-and-control—that is, requiring consumers to purchase EVs—may be the only regulatory mechanism to achieve Professor Jacobson's and Professor Williams' visions for complete automobile decarbonization.

218. There are considerable obstacles to consumer adoption of ZEVs over traditional gasoline-powered cars, as automobile market share data clearly demonstrate. ZEVs have been available in the U.S. for nearly two decades, yet despite generous federal and state financial incentives,[214] they accounted for 1% of U.S. light-duty vehicle sales in 2017.[215] The EIA estimates that electric and hybrid vehicle sales will comprise 13% of passenger vehicle sales by 2030, 17% by 2040, and 19% by 2050.[216,217]

219. Battery cost, recharging time, and the absence of infrastructure for out-of-home battery charging are key technical obstacles to widespread consumer adoption of ZEVs. Dramatic improvements in battery technology are necessary to bring electric vehicles to cost parity with gasoline-powered vehicles. At current cost levels, an electric vehicle costs less to operate than a gasoline-powered vehicle only if the price of oil exceeds $350 per barrel.[218] In the last five

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[214] An example of direct financial incentive is the federal income tax credit of $2,500 to $7,500 for all-electric and plug-in hybrid vehicles purchases in or after 2010. See "Federal Tax Credits for All-Electric and Plug-in Hybrid Vehicles," *U.S. Department of Energy*, https://www.fueleconomy.gov/feg/taxevb.shtml; U.S. Internal Revenue Service Bulletin: 2009–48, November 30, 2009, https://www.irs.gov/irb/2009-48_IRB#NOT-2009-89.

[215] Even if hybrid electric vehicles are considered, their market share in the U.S. has been at most merely 3.4% since 1999. Data from hybridcars.com and U.S. Department of Energy, Alternative Fuels Center.

[216] U.S. Energy Information Administration Report, "Annual Energy Outlook 2018," February 6, 2018, pp. 9, 114. This is under the reference (business-as-usual) EIA scenario from 2018. The reference case reflects current laws and regulations including sunset dates for laws that have them. The reference case also reflects trend improvement in known technologies and current views of leading economic forecasters and demographers. The potential impacts of proposed legislation, regulations, and standards are not included.

[217] The National Renewable Energy Laboratory Electrification Futures Study indicates that even in their "high" scenario, PHEVs only account for 84 percent of the light duty fleet in 2050. The "high" scenario represents "a combination of technology advancements, policy support and consumer enthusiasm that enables transformational change in electrification." See Trieu Mai et al., "Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States," Department of Energy Report #DE-AC36_08GO28308, 2018, pp. x, xii, https://www.nrel.gov/docs/fy18osti/71500.pdf.

[218] This calculation does not account for subsidies. Thomas Covert et al., "Will We Ever Stop Using Fossil Fuels?" *Journal of Economic Perspectives*, 2016, pp. 1–26, at p. 18. See also Jim Gorzelany, "Which (Of Only A Few)

years, oil prices have ranged from $26 to $111.[219] As for infrastructure, the DOE estimated in 2017 that 15 million battery electric vehicles and PHEVs would require 600,000 non-residential plugs and 25,000 direct current fast charging ("DCFC") plugs, and that roughly 8,000 uniformly distributed DCFC stations would be required to provide a minimum level of coverage in cities and towns such that a battery electric vehicle or PHEV would never be more than three miles from a charging station.[220] As of August 4, 2018, just 18,551 public electric charging stations were available in the U.S., over 4,500 of them located in California.[221] In Washington State there were only 792 charging stations.[222]

220. California has ambitious plans to accelerate the adoption of ZEVs, which include goals for the number of ZEVs in use; demand- and supply-side incentive programs and other regulatory mechanisms to induce the purchase of ZEVs; and public investment in the infrastructure necessary to support ZEVs.

a. California's most recently proposed plan (as of January 2018) calls for at least 5 million ZEVs on California roads by 2030, or approximately 20% of registered vehicles.[223]

b. Under the state's Clean Vehicle Rebate Project ("CVRP"), California residents receive up to $7,000 for the purchase or lease of a new, eligible ZEV or PHEV.[224]

Hybrids Make Financial Sense," *Forbes*, August 26, 2016, available at https://www.forbes.com/sites/jimgorzelany/2016/08/26/cheap-gas-means-few-hybrids-make-financial-sense-to-own/#1c23cdc85d7c.

219 "Crude Oil Prices: West Texas Intermediate (WTI) - Cushing, Oklahoma," *Economic Research Federal Reserve Bank of St. Louis*, August 1, 2018, https://fred.stlouisfed.org/series/DCOILWTICO.

220 Eric Wood et al., "National Plug-In Electric Vehicle Infrastructure Analysis," U.S. Department of Energy Report, September 2017, pp.iv 39.

221 "Alternative Fueling Station Counts by State," *U.S. Department of Energy*, August 4, 2018, https://www.afdc.energy.gov/fuels/stations_counts.html, accessed August 4, 2018.

222 "Alternative Fueling Station Counts by State," *U.S. Department of Energy*, August 4, 2018, https://www.afdc.energy.gov/fuels/stations_counts.html, accessed August 4, 2018.

223 Office of Governor Edmund G. Brown Jr. Press Release, "Governor Brown Takes Action to Increase Zero-Emission Vehicles, Fund New Climate Investment," January 26, 2018, https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/. Note that the 20% figure is an approximation. In 2017, 26 million automobiles and motorcycles were registered in California. If the number of registered vehicles increases by 2030, 5 million ZEVs would represent less than 20% of registered vehicles.

224 "Drive clean and save," *California Clean Vehicle Rebate Project*, https://cleanvehiclerebate.org/eng.

From 2010 to July 2018, CVRP paid $549 million in rebates for about 247,000 ZEVs and PHEVs (an average of about $2,200 per vehicle).[225]

c. On the supply side, California's proposed 2018 plan would implement a cap-and-trade system for ZEV credits. Under this system, each manufacturer must meet a minimum threshold for ZEV sales as a proportion of its total vehicle sales in California. Manufacturers earn credits either by selling ZEVs, or by purchasing credits from another manufacturer.[226] The ZEV threshold begins at 4.5% of sales in 2018, and increases to 22% of sales in 2025.[227]

d. California will invest a total of $2.5 billion over a period of eight years in subsidy payments and ZEV infrastructure (pending legislation approval).[228] The state's objective is to install 200 hydrogen-fueling stations and 250,000 vehicle charging stations by 2025.[229]

221. Nine other states (the "Section 177 States") have adopted California's ZEV regulation, as allowed by Section 177 of the Clean Air Act.[230] In 2013, seven of the Section 177 States and California set a collective goal of 3.3 million ZEVs on their roads by 2025.[231]

222. Despite the array of policies implemented to facilitate ZEV adoption, there is considerable uncertainty about whether California and the Section 177 States will meet their ZEV goals. In California, for example, ZEVs must comprise approximately 15% of total new

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[225] "CVRP Rebate Statistics," *California Clean Vehicle Rebate Project*.

[226] The number of credits awarded for a ZEV sale varies depending on certain vehicle characteristics.

[227] Small Volume Manufactures with less than 4,500 vehicle sales per year are not subject to the requirements. California Environment Protection Agency Presentation, "California's ZEV Regulation for 2018 and Subsequent Model Year Vehicles," 2016, pp. 1–51 at pp. 6, 11, 35.

[228] Office of Governor Edmund G. Brown Jr. Press Release, "Governor Brown Takes Action to Increase Zero-Emission Vehicles, Fund New Climate Investment," January 26, 2018, https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/.

[229] Office of Governor Edmund G. Brown Jr. Press Release, "Governor Brown Takes Action to Increase Zero-Emission Vehicles, Fund New Climate Investment," January 26, 2018, https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/.

[230] California Environment Protection Agency, Air Resources Board Report, "California's Advanced Clean Cars Midterm Review," January 18, 2017, p. E-1. The nine additional states are Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont.

[231] "Eight States Plan for 3.3 Million Zero-Emission Vehicles by 2025," *United States Department of Energy*, October 30, 2018, https://www.energy.gov/eere/vehicles/articles/eight-states-plan-33-million-zero-emission-vehicles-2025.

vehicle sales from 2018 through 2030 in order to meet the state's 2030 goal, but were just 4.7% of sales in 2017.[232] In the Section 177 States, progress toward the ZEV target adopted in 2013 has been sluggish at best. Annual ZEV sales have remained flat, both in absolute terms and as a proportion of total car sales.[233]

223. Setting aside the open question of consumer adoption of ZEVs over gasoline-powered vehicles, I turn to the question of the cost of Professor Jacobson's 100% ZEV vision. Suppose that California's current subsidy payment was sufficient to induce 100% of car buyers (rather than just 15%) to purchase a ZEV instead of a gasoline-powered vehicle. Assuming average sales of 2 million vehicles and an average subsidy payment of $2,400 yields a total outlay of $4.8 billion per year.[234] This amounts to more than 25% of spending under California's 2017 budget after excluding education, corrections, and health and human services.[235] Expanding the rebate program nationwide would require $20 billion of additional federal expenditure annually.[236]

2. Transportation: Aircraft

224. Under Professor Jacobson's timetable for decarbonization of air transportation, all new small, short-range aircraft must be electric by 2035, and all remaining new aircraft must be

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[232] ZEV sales in California was 96,731 in 2017, out of the total 2,047,632 vehicles sold in California that year. "Advanced Technology Vehicle Sales Dashboard," *Auto Alliance*, https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/. "California Auto Outlook: Comprehensive Information on the California Vehicle Market," *California New Car Dealers Association*, February 2018, https://www.cncda.org/wp-content/uploads/California-Covering-4Q-2017-1.pdf. 15 percent is calculated by taking the 5 million ZEV goal divided by approximately 34 million new light duty vehicle registrations from 2018–2030 (assuming the growth rate in new light duty vehicle registrations remains constant from 2018–2030 as the previous 10-year average).

[233] California Environment Protection Agency, Air Resources Board Report, "California's Advanced Clean Cars Midterm Review," January 18, 2017, pp. B-15–B-16.

[234] New vehicle sales in 2017 in California were 2.05 million. See "California Auto Outlook: Comprehensive Information on the California Vehicle Market," *California New Car Dealers Association*, February 2018. The average CVRP subsidy payment in 2017 was approximately $2,400. "CVRP Rebate Statistics," *California Clean Vehicle Rebate Project*.

[235] California's 2017 state budget after excluding K-12 and higher education, corrections, and health and human services was $19 billion. "Summary Charts," California State Budget – 2018–19, p. 18, Figure SUM-02, http://www.ebudget.ca.gov/2018-19/pdf/Enacted/BudgetSummary/SummaryCharts.pdf.

[236] Calculation assumes the average rebate per vehicle is $2,400 and sales of 8.5 million new light-duty vehicles in 2017: $2,400*$8.5 million=$20.4 billion. U.S. Energy Information Administration Report, "Annual Energy Outlook 2018," Table 39, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=48-AEO2018&cases=ref2018&sourcekey=0. The budget for the primary federal programs that support electric vehicle technologies is about $7.5 billion over 10 years, from 2009 through 2019. See Congressional Budget Office Report, "Effects of Federal Tax Credits for the Purchase of Electric Vehicles," p. 9, September 2012, https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/electricvehiclesone-col.pdf.

hydrogen fuel cell-electric hybrids by 2040.[237] Further, because Professor Jacobson maintains that U.S. energy-related CO_2 emissions will be zero by 2050, he implicitly assumes that the existing stock of airplanes will either be decommissioned or retrofitted to use electric- or hydrogen-based power, potentially before the end of their useful economic life. In contrast to Professor Jacobson, Professor Williams does not include an explicit plan for decarbonization of air travel in his model.

225. Professor Jacobson offers no evidence to establish any possibility that his stated goal can be met, and offers no evidence to establish when or at what cost these massive changes in aviation technology might materialize. In particular, he offers no evidence to establish (i) that prototype electric-powered or hydrogen fuel cell-electric hybrid aircraft will approach commercial viability by 2035–2040, (ii) that these technologies will capture 100% of sales of short- and long-range aircraft by 2040, (iii) that the necessary airport infrastructure changes will materialize and mature by 2040, or (iv) that airlines will scrap their existing aircraft.

226. Research on hydrogen- and electric-powered aircraft is in its infancy and focuses on small, experimental aircraft.[238] In discussing the long-run industry outlook, the Federal Aviation Administration and the two largest aircraft manufacturers, Boeing and Airbus, do not mention hydrogen- or electric-powered passenger or cargo aircraft.[239] Similarly, a Boeing representative stated in a recent interview that "large long-range commercial aircraft, like the Boeing 777 or 787, are unlikely to be displaced by electric aircraft in the foreseeable future."[240]

227. Further, examples of the development timelines for recently introduced aircraft demonstrate that Professor Jacobson's proposed goal—complete market acceptance of hydrogen- and electric-powered aircraft within 20 years—is not realistic. Airbus delivered the Airbus 380

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[237] Jacobson Report, p. 17.

[238] See, e.g., Samantha Masunaga, "No flying Tesla? That's because electric planes are a steeper challenge than electric cars," *L.A. Times*, September 9, 2016, http://www.latimes.com/business/la-fi-electric-aircraft-20160830-snap-story.html.

[239] Boeing Report, "Current Market Outlook: 2017 – 2036," June 19, 2017; Airbus Global Market Forecast, "Growing Horizons: 2017 / 2036," 2017.

[240] Marisa Garcia, "Future Proof: Fuel Cell Systems Could Power Aircraft Cabin Parts," *APEX*, February 5, 2018, https://apex.aero/2018/02/05/fuel-cell-systems-power-commercial-aircraft-cabin-parts, accessed on May 9, 2018.

more than 13 years after it first announced development plans.[241] Development of the Boeing 787 required eight years.[242]

228. Additionally, the production rate of new aircraft required to meet Professor Jacobson's proposal would be unrealistically high. Even after the development and first commercial use of a new airplane model, it takes time to produce each new unit. For context, in 2017 Boeing estimated that the number of North American airplanes in service would reach 10,130 by 2036 and estimated that 8,640 new planes would be produced from 2017 to 2036.[243] Conservatively holding the number of airplanes in service constant from 2036 to 2050, even if production of electric- and hydrogen-powered airplanes began immediately in 2035 (assuming the technology was ready by then), Professor Jacobson's timetable for zero GHG emissions leaves only 15 years to produce over 10,000 airplanes to replace the entire conventional U.S. fleet. This would require a production rate that substantially surpasses historical levels of production.

229. Finally, Professor Jacobson's proposed decarbonization timeline would require the premature retirement of operational airplanes. Based on a study by SGI Aviation, even if commercial production and use of electric and hydrogen-powered airplanes would begin in 2025, over 50% of conventional airplanes sold near 2025 would still have a useful economic life in 2050.[244] With 2018 list prices for passenger airplanes (of at least 100 seats) ranging from $77 million to $445 million,[245] the cost burden on commercial airlines would be astronomical if they

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[241] Airbus announced plans to develop an all-new large airliner in 1994 and began development in 2000. The first superjumbo Airbus entered service nearly seven years later, in October 2007. See David Bowed, "Airbus Will Reveal Plan for Super-Jumbo: Aircraft Would Seat at Least 600 People and Cost Dollars 8bn to Develop," *The Independent*, June 4, 1994, https://www.independent.co.uk/news/business/airbus-will-reveal-plan-for-super-jumbo-aircraft-would-seat-at-least-600-people-and-cost-dollars-8bn-1420367.html, accessed May 9, 2018; Peter Pae, "Airbus Giant-Jet Gamble OKd in Challenge to Boeing," *Los Angeles Times*, December 20, 2000, http://articles.latimes.com/2000/dec/20/news/mn-2453, accessed May 9, 2018. See also "A380 Superjumbo Lands in Sydney," *BBC*, October 25, 2007, http://news.bbc.co.uk/2/hi/business/7061164.stm accessed May 9, 2018.

[242] Boeing first announced development plans for the 787 Dreamliner on January 29, 2003, and over eight years later, on October 26, 2011, the Dreamliner flew its first commercial flight. See "History of the Boeing 787," *Seattle Times*, Associated Press, June 23, 2009, http://old.seattletimes.com/html/nationworld/2009373399_apusboeing787historyglance.html, accessed May 9, 2018; and Tim Kelly, "Dreamliner Carries Its First Passengers and Boeing's Hopes," *Reuters*, October 26, 2011, https://www.reuters.com/article/us-dreamliner/dreamliner-carries-its-first-passengers-and-boeings-hopes-idUSTRE79P02Q20111026, accessed May 9, 2018.

[243] Boeing Report, "Current Market Outlook: 2017 – 2036," June 19, 2017, p. 59.

[244] From 1980–2015, the average retirement age of U.S. aircraft was 26.5 years and only 10% of aircraft were retired before the age of 15. SGI Aviation Report, "Aircraft Retirements and Part-Out: Effective Use of Existing Trends and Opportunities in the Market," September 15, 2016.

[245] "About Boeing Commercial Airplanes," *Boeing*, http://www.boeing.com/company/about-bca/#/prices, accessed May 9, 2018; "Airbus Aircraft 2018 Average List Price (USD Millions)," *Airbus*,

were forced to replace these airplanes before the end of their useful life, as implicitly required by Professor Jacobson's proposal.

3. Industrial Energy Use

230. Both Professor Jacobson and Professor Williams state objectives for reduction of emissions in the industrial sector. Under Professor Jacobson's proposed timeline, all new devices, and all new high-temperature heating equipment for industrial applications must be electric by 2023.[246] As in the case of automobiles and aircraft, Professor Williams' proposal is somewhat less ambitious; he concludes that by 2050, the industrial sector can reduce its GHG emissions by as much as 84% relative to 2014 GHG emissions.[247]

231. Professor Jacobson and Professor Williams both appear to rely on little more than unsupported assumption. For example, Professor Williams' predicted emissions for the decarbonized industrial sector in 2050 assume that industrial firms will switch to low-carbon energy sources,[248] but he offers no explanation whatsoever of the factors that will induce firms to make the switch.

232. Technical feasibility is a serious impediment. For some energy-intensive industries that rely on energy sources other than electricity, manufacturing processes based on electricity have not been developed or proven at scale. Further, economic feasibility can be an impediment even when technical feasibility is not. Often the cost of manufacturing processes based on non-electric energy sources is lower than the cost of processes that rely on electricity. I describe two examples to illustrate these points: iron and steel, where economic feasibility is an impediment to electrification and reduced GHG emissions, and cement, which cannot be fully decarbonized. These examples illustrate that there are significant technical and economic barriers to the GHG mitigation that Professor Williams and Professor Jacobson predict.

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http://www.airbus.com/content/dam/corporate-topics/publications/backgrounders/Airbus-Commercial-Aircraft-list-prices-2018.pdf, accessed May 9, 2018.

[246] Jacobson Report, p. 16. See also Mark Z. Jacobson et al., "Low-Cost Solution to the Grid Reliability Problem with 100% Penetration of Intermittent Wind, Water, and Solar for All Purposes," *Proceedings of the National Academy of Sciences* 112, no. 49, 2015 ("Jacobson 2015b"), pp. 15060–15065, at p. 15060.

[247] Williams Report, Exhibit D, p. D38.

[248] See, e.g., Williams Report, Exhibit D, p. D52, noting that for firms whose industrial processes rely on steam, coal, coke, and petroleum fuels "are replaced by" electricity or pipeline gas.

233. EIA survey data indicate that the iron and steel industry is energy-intensive—as of 2014, it accounted for just 0.6% of U.S. GDP, but 6% of industrial energy use[249]—but has made significant progress in electrification of manufacturing. However, the production technology that Professor Williams proposes can decarbonize only part of iron and steel production, and its costs are higher than the conventional production methods.[250]

234. I understand that steel-making is a two-stage process. The first stage reduces iron ore, while the second stage further processes the reduced iron ore into steel.[251] In the last 50 years, U.S. manufacturers have electrified the majority of the second stage of the production process.[252] However, there does not exist today a commercially mature zero-emission process for the first stage of production. Research into the possibility of using hydrogen in the reduction of iron ore is ongoing, but industry press suggests that an economically viable hydrogen-based process is decades away.[253]

235. Additionally, I understand that the direct reduced iron ("DRI") method that Professor Williams proposes is a broad category for processes that reduce iron in its solid state,[254] and that the DRI method has been proven to reduce emissions.[255] However, the unit cost of production based on the DRI method is more than twice the cost of production based on traditional

[249] U.S. Energy Information Administration, 2014 MECS Survey Data, October 2017, Table 1.1 First Use of Energy for All Purposes (Fuel and Nonfuel), 2014. The iron and steel industry produced goods in 2014 with an estimated value of about $113 billion in 2014 compared to a total U.S. 2014 GDP of $17.4 trillion. Michael D. Fenton, "Iron and Steel," U.S. Geological Survey Mineral Commodities Summaries, January 2015, https://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/mcs-2015-feste.pdf.

[250] Williams Report, Exhibit D, p. D52.

[251] Since pure iron (Fe) is not readily available in nature due to its reactivity with air and moisture, iron ore (Fe_2O_3) mined is reduced to pure iron when heated in a furnace at high temperatures in the presence of hydrocarbon-rich gases. See "Iron and Steel," Energy Technology Systems Analysis Programme, International Energy Agency, May 2010. F. Grobler and R.C.A. Minnitt, "The Increasing Role of Direct Reduced Iron in Global Steelmaking," *Journal of the South African Institute of Mining and Metallurgy*, March/April 1999.

[252] In 2015, the majority (65%) of raw steel production plants in the US operated using electric arc furnaces. See Tom Balcerek, "Turning Away from Blast Furnaces Still Leaves Problems for Steel Industry," *Platts*, October 20, 2015, blogs.platts.com/2015/10/20/blast-furnaces-problems-steel-industry/.

[253] Stuart Burns, "Hydrogen to Replace Coking Coal in the Reduction of Iron Ore Steelmaking? Maybe One Day," *Metal Miner*, February 13, 2017, https://agmetalminer.com/2017/02/13/hydrogen-to-replace-coking-coal-in-the-reduction-of-iron-ore-in-steelmaking-maybe-one-day/.

[254] Direct reduced iron ("DRI") is produced by removing oxygen from iron ores in the solid state (in the form of lumps or pellets). Natural gas or coal are used as a reducing agent to enable this process. "Iron and Steel," Energy Technology Systems Analysis Programme, International Energy Agency, May 2010. "DRI Production," *International Iron Metallics Association*, https://www.metallics.org/dri-production.html, accessed July 13, 2018.

[255] "Iron and Steel," Energy Technology Systems Analysis Programme, International Energy Agency, May 2010, Table 1, p. 6.

methods.[256] Besides technology and cost issues, shipping and handling of the iron from the DRI process also requires an inert atmosphere to prevent self-heating and fires.[257]

236. Cement manufacturing is another example of an energy-intensive industry. According to the EIA, cement manufacturing is "the most energy intensive of all manufacturing industries"; the cement industry's share of national energy use is roughly 10 times its share of the nation's gross output of goods and services.[258] Neither Professor Williams nor Professor Jacobson provides guidance for reduction of emissions from the cement industry, and for good reason—the technology to electrify its production has not yet matured. I am aware of two pilot projects seeking to decarbonize cement production. The first, a pilot study in Sweden, concluded that electric furnaces are largely unsuitable.[259] The second project, SOLPART, aims to develop solar processes in substitution of fossil fuels used as part of cement production, but thus far has failed to do so.[260] To date, SOLPART has failed to reach the required temperature level.[261]

237. Further, more than half of GHG emissions from cement production are attributable to the production process itself, rather than to generation of energy used to fuel production. The literature indicates that the chemical reaction involved in one part of the production process accounts for more than half of GHG emissions. Substitution to a zero-emission energy source cannot eliminate these emissions.[262] Even using zero-emission energy sources, the cement industry CO_2 emissions will not be reduced to zero.

256 As of 2010, unit cost was $92 per ton (including energy inputs) using a conventional blast furnace and basic oxygen furnace, but $214 per ton for production based on DRI and electric arc furnace combinations. "Iron and Steel," Energy Technology Systems Analysis Programme, International Energy Agency, May 2010, p. 1.

257 International Iron Metallics Association Report, "Ore-Based Metallics: Adding Value to the EAF," May 2017, p. 21, http://seaisi.org/seaisi2017/file/file/full-paper/Session7B%20Paper2.pdf.

258 See "The Cement Industry Is the Most Energy Intensive of All Manufacturing Industries," U.S. Energy Information Administration, July 1, 2013, https://www.eia.gov/todayinenergy/detail.php?id=11911.

259 Clinker sintering, a critical step in cement production, requires a temperature of 1450°C, but electric furnaces that reach this temperature typically do not have the cylindrical shape necessary to produce clinker. See Cédric Philibert, "Renewable Energy for Industry: From Green Energy to Green Materials and Fuels," International Energy Agency Report, 2017, p. 43. See also Vattenfall Press Release, "Vattenfall and Cementa Focusing on Zero Emissions," June 29, 2017, https://group.vattenfall.com/press-and-media/news--press-releases/pressreleases/2017/vattenfall-and-cementa-focusing-on-zero-emissions.

260 Cédric Philibert, "Renewable Energy for Industry: From Green Energy to Green Materials and Fuels," International Energy Agency Report, 2017, p. 42

261 Cédric Philibert, "Renewable Energy for Industry: From Green Energy to Green Materials and Fuels," International Energy Agency Report, 2017, p. 43.

262 Lisa J. Hanle et al., "CO_2 Emissions Profile of the U.S. Cement Industry," U.S. Environmental Protection Agency Report, pp. 5–6. See also Cédric Philibert, "Renewable Energy for Industry: From Green Energy to Green Materials and Fuels," International Energy Agency Report, 2017, p. 42 ("More than half of the cement industry's

B. Plaintiffs' Experts Understate Costs of their Proposed Energy Systems

238. Plaintiffs' experts' understate the costs of their proposed energy systems. Moreover, the estimates they provide are necessarily highly uncertain, as they both forecast energy costs over nearly 40 years. While Professor Williams acknowledges the unavoidable uncertainty in his estimates, Professor Jacobson papers over the issue and fails to report the uncertainty in the forecast data on which his cost estimates rely. As for energy costs, neither Professor Jacobson nor Professor Williams considers the full range of costs associated with their proposed energy systems. Both focus narrowly on the costs of energy supply. Neither offers a model of energy demand (i.e., a model in which the quantity of energy consumed responds to the price of energy), and neither attempts to estimate the broad economic effects that would arise in response to an increase in the price of energy ("macroeconomic effects"). As I explain below, other research shows that the macroeconomic effects of decarbonization are substantially larger than the cost estimates that Professor Williams provides. Finally, I find Professor Jacobson's conclusion as to electricity costs under his "WWS" system is incorrect. Professor Jacobson asserts that electricity costs would be lower under his proposed system than under the current, conventional energy system. As I explain below, inspection of his cost analysis reveals that this incorrect result depends entirely on unsupported assumptions as to the trajectory of initial investment costs over time.

1. Plaintiffs' Experts' Cost Estimates Are Highly Uncertain

239. The cost estimates that Professor Williams and Professor Jacobson present rely on a wide variety of assumptions as to technical progress across a wide variety of scientific and engineering domains, and further assumptions as to the trajectory of energy demand, technology costs, and fossil fuel prices over a period of nearly 40 years. As a result, their estimates must be regarded as highly uncertain.

240. Professor Williams documents the degree of uncertainty in his estimates of the incremental cost of his proposed energy system, and concedes that "technology cost and fossil

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CO_2 emissions are process emissions from the clinker production process, in which limestone ($CaCO_3$) is heated to produce lime (CaO) and thus release CO_2.").

fuel projections 40 years into the future are *very uncertain*."[263] He estimates that incremental costs for 80% mitigation will be 0.8% of 2050 GDP. However, the dispersion in Professor Williams' estimates is quite large: the 25th and 75th percentile values for estimated incremental costs are, respectively, -0.2% and 1.8% of GDP, and 25% of estimates are greater than 1.8% of GDP.[264] Setting aside the factors that cause Professor Williams to understate the cost of his proposed transformation, this means that energy expenditure as a proportion of GDP could increase by 23% or more over its level under the current energy system.[265]

241. Professor Jacobson offers little information to describe the degree of uncertainty in his cost estimates. He reports estimates of average costs for electricity in 2050 by generation technology,[266] but he reports nothing about the uncertainty associated with the forecast data from which he constructs his cost estimates.[267] For example, 2040 fuel prices in the EIA 2014 forecast Professor Jacobson relies on vary from their median estimate by -41% to 222% for coal, -36% to 53% for natural gas, and -47% to 72% for oil.[268] This variation does not appear in Professor Jacobson's model. Instead Professor Jacobson extends the EIA baseline case projection to 2050 and arbitrarily uses +/- 10% as his high and low scenarios.[269] As a result, Professor Jacobson's cost estimates do not have a known error rate.

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[263] Williams Report, Exhibit D, p. D27. Emphasis added.

[264] Williams Report, p. 3. See also Williams Report Exhibit D, pp. D16, D43.

[265] Energy expenditures were 8% of GDP on average from 2005–2016. An increase equivalent to 1.8% of GDP represents a 23% increase, since 9.8 / 8.0 = 1.23. See U.S. Energy Information Administration Report, "July 2018 Monthly Energy Review," Table 1.7 Primary Energy Consumption, Energy Expenditures, and Carbon Dioxide Emissions Indicators.

[266] Mark Z. Jacobson et al., "100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States," *Energy & Environmental Science* 8, no. 7, 2015 ("Jacobson 2015a"), Table 5.

[267] Data that Professor Jacobson relies on to construct estimated average costs include a forecast of power plant capacity, fuel costs, and transmission and distribution costs published by the EIA. See Jacobson 2015a, Supplemental Information, pp. 45, 52, 60, 61.

[268] See U.S. Energy Information Administration Report, "Annual Energy Outlook 2014," Table: Electric Power Projections by Electricity Market Module Regions, All Scenarios.

[269] Jacobson 2015a, Supplemental Information, p. 60.

2. Plaintiffs' Experts Cost Estimates Are Incomplete and Understate the Full Economic Impact of Decarbonization

242. Neither Professor Jacobson nor Professor Williams presents a complete analysis of the costs associated with their proposed energy systems. The estimates they present are incomplete and therefore understate the full costs to society of their proposed energy systems.

243. A complete accounting of economic impact must include cost changes in three different categories: (i) energy supply costs; (ii) costs for replacement of the stock of equipment necessary to use energy (e.g., appliances, systems for heating, ventilation, and cooling of residential and commercial buildings, and equipment for industrial and manufacturing processes); and (iii) macroeconomic effects arising from an energy price shock (i.e., effects throughout the economy, rather than the energy sector alone, in response to a change in energy prices). [270]

244. Professor Jacobson considers only the cost of electricity (i.e., the average or "levelized" cost of electricity),[271] and fails to analyze or report costs in the other two categories. Given these omissions, his conclusions as to average cost are not a reliable indicator of the overall cost to society of his proposed energy system. Moreover, as I show below, his estimates of average cost are incorrect.

245. Professor Williams' analysis is marginally more complete, as it includes both energy supply costs and an estimate of costs associated with the stock of end-use equipment and infrastructure. However, Professor Williams fails to include any estimate of the macroeconomic effects of his proposed energy system. A thorough analysis would account for the economic impact of changing energy costs outside of the energy sector. Indeed, Professor Williams states he does not account for changes in energy demand in response to higher energy prices, that

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[270] As to the second category, the energy systems proposed by Professors Jacobson and Williams would require replacement of end-use infrastructure. For example, both Professor Jacobson and Professor Williams call for industrial power users to adopt new manufacturing processes using electricity rather than high-carbon fuels, which would require new manufacturing equipment. See Jacobson Report, p. 16 and Williams Report, Exhibit E, p. E52.

[271] Levelized costs measure the unit cost of electricity from a generation facility over the operating life of the facility. Levelized cost includes initial capital investment, financing costs, fixed and variable operating costs, maintenance costs, and fuel costs over the life of the facility. See, e.g., U.S. Energy Information Administration Report, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018," March 2018, https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf. I refer to levelized cost as average cost.

"economic accounting in PATHWAYS *is limited to energy system costs*," and that "PATHWAYS…*does not include pricing or macroeconomic feedback*."[272]

246. Professor Williams' failure to examine the impact of changes in energy prices on the overall economy is a critical omission. Academic studies have shown that these macroeconomic effects comprise a large proportion of the overall cost of decarbonization. For example, the Energy Modeling Forum 24 ("EMF 24") studies,[273] which use economic models to examine the macroeconomic impact arising from climate policy intervention and decarbonization, show that estimated consumption losses and losses in economic output (GDP) are on the order of $1 to $6 trillion.[274] Professor Williams' cost estimates are an order of magnitude smaller; he reports that the median incremental cost for his proposed energy system is "just over $300 billion."[275]

247. Given the importance of macroeconomic effects, the cost estimates that Professor Williams presents are not a reliable indicator of the overall cost of his proposed system to society.

3. Professor Jacobson Understates the Cost of Electricity Under His Proposed Energy System

248. Professor Jacobson asserts that the cost of electricity in 2050 would be lower under his proposed 100% WWS system than under a projection of the current U.S. energy system (the "business-as-usual system").[276] I conclude that Professor Jacobson's conclusion is incorrect because his analysis understates the cost of electricity under his proposed energy system.

249. A simple comparison with Professor Williams' results suggests that Professor Jacobson's conclusion is implausible. Professor Williams concludes that 80% mitigation of U.S. GHG

[272] Williams Report, Exhibit D, pp. D27. Emphasis added. PATHWAYS is one of the models Professor Williams uses to assess the feasibility of reducing GHG emissions by 80% of 1990 levels. Williams Report, Exhibit D, p. D14.
[273] EMF 24 is an energy modeling research project coordinated by the Stanford University Energy Modeling Forum that studied the economic impact of various climate intervention policies (e.g., economy-wide cap and trade, and sector-specific policies for transportation and electricity generation) given different GHG reduction goals (50% and 80%) and varying assumptions about technology. The studies compared results from seven different energy-economic models using a variety of measures, including carbon price, consumption loss, GDP loss, and equivalent variation. See Allen A. Fawcett et al., "Overview of EMF 24 Policy Scenarios," *Energy Journal* 35, 2014 ("EMF 24 Policy Scenarios").
[274] EMF 24 Policy Scenarios, Figure 7 and Figure 9.
[275] Williams Report, Exhibit D, p. D43.
[276] Jacobson Report, p. 3. See also Jacobson 2015b, p. 15064 and Jacobson 2015a, pp. 2104–2105.

emissions—a *lower* level than Professor Jacobson promises—would cause energy expenditures to increase by 14% relative to the current energy system,[277] and that costs would increase still more to attain the higher level of mitigation (96%) necessary to reduce CO_2 concentrations to 350 ppm by 2100.[278] Professor Jacobson promises an even higher level of mitigation (100%) under his proposed energy system, yet claims electricity costs under this system would be *lower* than costs (excluding social costs) under the current fossil-fuel-based energy system.

250. Professor Jacobson's conclusion as to electricity costs depends on two elements of his analysis that understate the cost of electricity under his proposed energy system.

251. First, Professor Jacobson assumes in his analysis of electricity generation costs that initial capital costs for wind and solar generation facilities will fall much more rapidly under his 100% renewable scenario than under the reference case ("business-as-usual") scenario.[279]

252. This assumption has a decisive impact on the relative cost of electricity in Professor Jacobson's 100% renewable and conventional scenarios. I find that absent the assumption that costs decline at a dramatically accelerated rate in the 100% renewable scenario, electricity costs in the 100% renewable scenario are higher than in the conventional scenario.[280] Professor Jacobson's conclusion that his proposed 100% renewable energy system yields lower electricity prices collapses without his aggressive and unsupported assumption that costs fall more rapidly in the 100% renewable scenario.

253. Second, Professor Jacobson relies on artificially low discount rates in his computation of average costs. While he applies the same rate to both energy systems—his proposed 100% renewable system, and the business-as-usual system used as a comparator—the effect of his

[277] See Williams Report, Exhibit E, p. E30, noting that "average retail electricity rates are only modestly higher (14%)" than rates under a business-as-usual scenario.
[278] Williams Report, pp. 11–12.
[279] For example, by 2050, the levelized initial capital cost for on-shore wind power is 2.25 cents per kWh in the 100% renewable scenario, and 2.98 cents per kWh in the business-as-usual scenario, despite the fact that costs today are identical. See Jacobson 2015a, Supplemental Information, Table S13.
[280] Professor Jacobson reports that the levelized cost of electricity is 9.78 cents / kWh in the 100% renewable scenario and 10.55 cents / kWh in the conventional scenario. After removing the accelerated cost decline assumption, costs in the renewable and conventional scenarios are, respectively 11.33 cents / kWh and 10.55 cents / kWh. Jacobson 2015a, Table 6.

mistake is to overstate costs in the business-as-usual scenario relative to costs for the 100% renewable system.[281]

254. Professor Jacobson uses discount rates of 1.5%, 3%, and 4.5%.[282] These rates are well below those used in other estimates of levelized costs, and well below corporate borrowing costs in capital markets. For example, Lazard—a widely used source for energy costs—assumes an 8% cost of debt and 12% cost of equity in its published estimates of levelized energy costs.[283] Further, average interest rates on 15- and 30-year high-quality corporate bonds over the last 25 years have been, respectively, 6.1% and 6.6%.[284] The IPCC baseline discount rate for calculating the cost from wind and solar investments is 8%.[285]

255. Professor Jacobson attempts to justify these rates on public policy grounds as "social discount rates" that should be low because electricity projects are long-lived and have intergenerational effects.[286] However, one cannot make investment decisions based on "social discount rates." The appropriate discount rate is the market rate of interest, as this measures the opportunity cost of the investor's capital.

C. Plaintiffs' Experts' Proposed Energy Systems Would Require Regulatory Intervention on a Large Scale

256. Even if Plaintiffs' experts' proposals were technically feasible and properly accounted for costs, they gloss over or ignore the political and economic barriers to implementation. Implementation of their proposals would require extensive changes across the economy, not only

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[281] The reason for this is straightforward. The 100% renewable system has no fuel costs, hence most costs are incurred during initial construction. The conventional energy system, on the other hand, incurs fuel costs over the operating life of the system. As a result, the computation of discounted costs is more sensitive to the choice of discount rate.
[282] See Jacobson 2015a, Supplemental Information, Table S13.
[283] "Lazard's Levelized Cost of Energy Analysis – Version 11.0," *Lazard*, November 2017, https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf.
[284] Federal Reserve Bank of St. Louis, 15-Year High Quality Market (HQM) Corporate Bond Spot Rate, https://fred.stlouisfed.org/series/HQMCB15YR; 30-Year High Quality Market (HQM) Corporate Bond Spot Rate https://fred.stlouisfed.org/series/HQMCB30YR.
[285] Christopher T. M. Clack et al., "Supporting Information for the Paper 'Evaluation of a Proposal for Reliable Low-Cost Grid Power with 100% Wind, Water, and Solar,'" *PNAS*, 2017, p. 8.
[286] Jacobson 2015a, Supplemental Information, p. 44. Social discount rates depend on relative time preferences. For example, given a choice between policy that ensures rapid short-term growth but limited long-run growth, and policy that ensures long-run growth, the first policy would be preferred given a high rate of time preference, and the latter policy would be preferred given a low rate of time preference. See, e.g., William D. Nordhaus, "A Review of the *Stern Review on the Economics of Climate Change*," *Journal of Economic Literature* 45, no. 3, 2007, p. 690.

in the energy sector but in many other parts of the economy such as transportation, industry, residential housing, commercial real estate, and consumer goods (e.g. appliances). Plaintiffs' experts' do not provide an accurate sense of the magnitude of changes that would need to occur to implement their proposals. Additionally, they provide no evidence that their proposals can be accomplished in the context of a market economy.

257. Implementing Plaintiffs' experts' proposals would require wide-ranging changes across the economy. According to the *Report of the High-Level Commission on Carbon Prices* (co-authored and cited by Professor Stiglitz), "[a]chieving the Paris Agreement temperature target requires a large-scale transformation of economic activity and the underlying systems."[287] Furthermore, the High-Level Commission recognizes that what is required is substantial including both structural and technological changes, involving "large uncertainties." The changes are not simply technological, but may impact "social norms." [288] Plaintiffs' experts do not explain what such an undertaking may entail.

258. The scope of decisions that would need to be influenced to be consistent with Plaintiffs' experts' proposed energy systems is immense. Essentially Plaintiffs require not only actions by the U.S. government, but also full support by state regulators, as well as participation and adoption by all producers and consumers of energy. The energy system affects choices regarding what capital to invest in, what areas to focus R&D on, what products to purchase, how new buildings should be designed, how plants should operate, and many others. For example, electrifying the steel industry will require developing new processes and retrofitting existing plants. The government, at present, does not directly control the choices of businesses in the industry as to what R&D to pursue or what capital investments to make.[289]

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[287] UNFCCC Report, Carbon Pricing Leadership Coalition, "Report of the High-Level Commission on Carbon Prices," May 29, 2017, p. 6.

[288] "The required action [to keep a temperature rise below 2 degrees C] implies structural change, learning, experimentation, and technological changes, and involves large uncertainties. These uncertainties include those related to the availability and cost of various technologies (e.g., the availability of CCS at scale, at reasonable cost), the social and political acceptability of some technologies (e.g., nuclear energy or large-scale land mobilization for biofuel production), the quality of policies, and possible changes in consumption patterns or social norms (e.g., related to transportation or the human diet and meat consumption)." UNFCCC Report, Carbon Pricing Leadership Coalition, "Report of the High-Level Commission on Carbon Prices," May 29, 2017, p. 7.

[289] Even if one argues that government does work in R&D, its contributions are small relative to the private sector. In 2015, approximately 69% of R&D came from the private sector. See "US R&D Spending at All-Time High, Federal Share Reaches Record Low," American Institute of Physics, Nov. 8, 2016, https://www.aip.org/fyi/2016/us-rd-spending-all-time-high-federal-share-reaches-record-low.

259. The case studies described earlier provide examples of the barriers that will impede implementation of Plaintiffs' experts' energy system proposals. In transportation, a consumer may have a preference for gas-fueled cars. How would they be convinced to buy an electric vehicle? In industry, manufacturers tend to select the most cost-effective approach. How is an iron manufacturer going to be convinced to select the twice as expensive (but lower emission) DRI method? In cases where personal preferences, ingrained habits, or cost considerations conflict with the lower-emissions choice, how are incentives to be aligned?

260. Plaintiffs' experts do not provide concrete plans to align the incentives of economic agents with their energy system proposals. For example, Professor Williams and Professor Jacobson do not provide a clear mechanism for how to induce firms to switch to electric or hydrogen-powered energy. What type of policies will need to be put in place to incentivize or force conversion? What are the costs of these programs?

261. Professor Williams does acknowledge the need for substantial policy support in his Exhibit E, which provides a list of 10 key policy requirements to support deep decarbonization.[290] However, Professor Williams' recommendations raise questions about the economic system that would be consistent with his proposals. For example, he states that policy should "create the right kinds of competition" and indicates that "scarce biomass feedstocks" are being "[misallocated]."[291] Economics suggests that scarce resources will be allocated to their highest valued use by prices in a market without the need for "encouraging" certain "kinds of competition." Other policy requirements that Professor Williams mentions include:

- "Develop institutional structures for coordination across sectors."[292]
- "Enable the required rates of consumer adoption"[293]
- "Anticipate investment needs and build a suitable investment environment."[294]

[290] Williams Report, Exhibit E, p. E14–15.
[291] Williams Report, Exhibit E, p. E69.
[292] Williams Report, Exhibit E, p. E67.
[293] Williams Report, Exhibit E, p. E70.
[294] Williams Report, Exhibit E, p. E64.

- "Integrate supply- and demand-side planning and procurement."[295]
- "Minimize inequitable distributional effects."[296]
- "Limit cost increases faced by consumers."[297]

262. These requirements suggest that large scale economic direction and coordination is required. Entrusting economic organization to a technocrat raises various concerns including issues of efficiency.[298] There are several examples of failed attempts at centrally planning economies.[299] Again, from an economics perspective, it is generally considered best to let markets allocate resources.[300]

263. The policies also indicate that there could be non-trivial impacts on consumers in terms of costs and the distribution of those costs. The issues that the policies must address suggest that the impacts of pursuing these goals are widespread with ramifications across the entire economy.

264. Not only is the volume of policies required large, the policy tools to bring them about come with a price and their own set of complications. Professor Williams discusses various policy tools to bring about energy transformation: "pricing, emissions caps, consumer rebates, producer subsidies, performance standards, technology mandates, public-private partnerships, and (research, development, and demonstration) RD&D support."[301] As shown with the example of electric cars, influencing behavior with incentives can be quite costly. Mandates and standards, on the other hand, shift costs to individuals and businesses, but still require the costs of enforcement.

265. Professor Jacobson's and Professor Williams' goals are unrealistic considering the scope of the decisions that would need to be influenced and the government intervention required. They have not demonstrated how decisions made by economic agents other than the federal

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[295] "The capability to provide demand-side flexibility at the required capacity, spatial, and time scales must be planned and procured in tandem with supply-side resources, and on the operational side wholesale electricity markets and reliability standards must be re-designed to work on both sides." Williams Report, Exhibit E, p. E68.
[296] Williams Report, Exhibit E, p. E73.
[297] Williams Report, Exhibit E, p. E72.
[298] "Principles of Economics," N. Gregory Mankiw, 2004, Third Edition, p. 150.
[299] "IMF Projects Venezuela Inflation Will Hit 1,000,000 Percent in 2018," *Reuters*, July 23, 2018, https://www.reuters.com/article/us-venezuela-economy/imf-projects-venezuela-inflation-will-hit-1000000-percent-in-2018-idUSKBN1KD2L9, accessed August 13, 2018.
[300] See, for example, "Principles of Economics," N. Gregory Mankiw, 2004, Third Edition, pp. 9-10.
[301] Williams Report, Exhibit E, p. E15.

government will be made to align with their proposals within the framework of a market economy.

266. Additionally, Professor Jacobson and Professor Williams do not consider all of the ramifications of implementing these policies. For example, what is the impact of policies that force energy consumers to switch to electricity or hydrogen? Some industries may choose to relocate over-seas due to higher production costs. If so, are these policies simply shifting non-zero emissions industries elsewhere, undermining any decrease, and potentially increasing global emissions? Such essential considerations for policy makers are simply ignored in Plaintiffs' experts' proposals.

D. Plaintiffs' Experts' Proposed Energy Systems Deviate from Consensus Views Regarding Decarbonization

267. The lack of feasibility of Plaintiffs' experts' proposals is supported by the fact that Professor Jacobson's and Professor Williams' proposed energy systems, implementation timelines, and estimated costs are not consistent with the conclusions set forth in a large body of literature that studies the problem of decarbonization and GHG mitigation. While the conclusions set forth in this literature as to the feasibility, cost, and timing of different levels of mitigation are not uniform, Professor Jacobson's and Professor Williams' conclusions are well outside the range in several dimensions. In particular, they assert greater emissions mitigation will be possible at lower costs than does most of the literature. When the literature does include emissions mitigation closer to the levels in the proposals, it relies on the assumption of idealized policy scenarios that will not hold in the practical applications of Professor Jacobson and Professor Williams. I discuss these points further in what follows and also examine the literature that Professor Jacobson claims supports his proposal.

268. The mitigation goals of both Professor Williams and Professor Jacobson are overreaching compared to the analysis of a large body of research.[302] In contrast to Professor Jacobson and

[302] The EMF 24 examines mitigation scenarios up to 80% relative to 2005. See Leon E. Clarke et al., "Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise," *Energy Journal* 35, 2014, p. 9. The IPCC states that only "a limited number of studies provide scenarios that… are characterized by concentrations below 430 ppm CO2-eq by 2100 and 2050 emission reduction between 70% and 95% below 2010." See IPCC Report, "Climate Change 2014 Synthesis Report Summary for Policymakers," 2014, p. 21.

Professor Williams, many studies do not even examine the possibility of 96% or 100% mitigation. For example, the California Council on Science and Technology ("CCST") concludes in its extensive analysis of decarbonization that (i) 60% mitigation by 2050 is feasible given technologies available today; and (ii) 80% mitigation may be feasible, but will be difficult, and will require solutions to the fuels problem that are not available today (in contrast to Professor Williams' analysis, which purportedly uses only available technology).[303]

269. Similarly, the EMF 24[304] studies find that (i) mitigation of 50% to 80% will require a dramatic transformation of the energy system;[305] (ii) costs will be higher with fewer available technologies;[306] (iii) the ability of models to produce mitigation scenarios is not sufficient to draw conclusions about the "feasibility" of these scenarios in a more applied sense;[307] and (iv) judgments of feasibility are ultimately bound up in subjective assessments of whether the U.S. would be willing and capable of taking on the transformation required to meet the mitigation goals, including bearing the associated macroeconomic costs and undergoing the required technological, institutional, and social transitions.[308] The EMF 24 studies conclude that going from 50% to 80% mitigation requires that the bulk of additional emissions reductions come from non-electric sectors, which require increasingly higher costs.[309]

270. Besides adopting more aggressive GHG emission reduction targets than others (i.e., deeper emissions reductions within a shorter time frame), Professor Jacobson and Professor Williams assume faster rates of growth in renewable energy generation capacity and greater rates of decline in the carbon intensity of U.S. economic activity, often at much lower costs than reflected in most of the literature on GHG transition pathways for the U.S. Professor Jacobson's

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303 Jane C. S. Long, "California's Energy Future: The View to 2050," California Council on Science and Technology Report, May 2011, pp. 43–45.
304 The Energy Modeling Forum is a model intercomparison project that investigates the power sector and the economy.
305 Leon E. Clarke et al., "Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise," *Energy Journal* 35, 2014, p. 9.
306 Leon E. Clarke et al., "Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise," *Energy Journal* 35 2014, p. 29–30.
307 Leon E. Clarke et al., "Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise," *Energy Journal* 35, 2014, p. 20.
308 Leon E. Clarke et al., "Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise," *Energy Journal* 35, 2014, p. 20.
309 Leon E. Clarke et al., "Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise," *Energy Journal* 35, 2014, p. 21.

combination of a 100% GHG emissions reduction target and the target year of 2050 at little or no putative cost goes well beyond what others have presented in even their most optimistic scenarios. The CCST summary study states that the reduction from 60% to 80% will require significant levels of research, technology development, and innovation, suggesting that the marginal cost of mitigation is significantly higher at levels above 80% (and is based on technology that does not yet exist or has not been proven at scale).[310] One EMF 24 study found that emissions reduction costs start to increase exponentially relative to the emissions reduction benefits, with this "knee" in the marginal cost of abatement curve occurring around the 50% to 60% emission reduction target.[311]

271. Although both Professor Jacobson and Professor Williams focus only on U.S. transitions to low-GHG futures by 2050, it is instructive to look briefly at projections of the costs of deep transitions to very low GHG emissions levels at the global scale through the end of the century, to see if there are any very low cost pathways that get global GHG emissions down near zero by mid-century. The last IPCC review of such scenarios shows a small number of very idealized global scenarios with near-zero GHG emissions by the end of the century, but not by 2050 and not at zero or very low costs.[312]

272. Even Professor Williams' higher cost range may be overly optimistic. Compared to EMF 24, Professor Williams' cost estimate is on the low end of the range,[313] and does not account for various demand-side costs or macroeconomic impacts, which could increase costs.[314] Furthermore, Professor Williams' target of 80% reduction is relative to 1990 levels while the

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[310] Jane C. S. Long, "California's Energy Future: The View to 2050," California Council on Science and Technology Report, May 2011, p. 45.

[311] Sugandha D. Tuladhar et al., "Interaction Effects of Market-Based and Command-and-Control Policies," *Energy Journal* 35, 2014, p. 78.

[312] IPCC Report, "Climate Change 2014 Synthesis Report Summary for Policymakers," 2014, pp. 20, 24.

[313] In his report, Professor Williams states: "From a cost standpoint, the PATHWAYS results ($1 to $2 trillion) are consistent with those found in the EMF 24 studies, which ranged from $1 to $4 trillion for most of the 80% emission reduction scenarios." Williams Report, Exhibit D, p. D76. PATHWAYS is one of the models Professor Williams uses to assess the feasibility of reducing GHG emissions by 80% of 1990 levels. Williams Report, Exhibit D, p. D14.

[314] "PATHWAYS calculates total energy system costs, and does not model changes in service demands in response to higher prices." Williams Report, Exhibit D, p. D76. "PATHWAYS uses a static forecast of activity levels based on the *AEO* [U.S. Department of Energy's *Annual Energy Outlook*], and thus does not include pricing or macroeconomic feedbacks." Williams Report, Exhibit D, p. D27. PATHWAYS is one of the models Professor Williams uses to assess the feasibility of reducing GHG emissions by 80% of 1990 levels. Williams Report, Exhibit D, p. D14.

EMF 24 scenarios are with respect to 2005 levels.[315] Since U.S. emissions grew by about 20% between 1990 and 2005, this implies that Professor Williams uses a more challenging baseline than that examined by EMF 24.[316] Finally, the only EMF 24 scenarios that considered 80% reduction of emissions by 2050 relative to 2005 were based on assumptions of a perfectly implemented cap-and-trade system.[317]

273. These are very strong and idealistic assumptions, implying that these scenarios were developed as "what if" scenarios and were not meant to provide a realistic picture of what might ultimately be feasible at the federal, state, local, firm, or household levels.[318] The costs associated with these assumptions are therefore the lower bound of what is possible. Once institutional considerations at all levels of the U.S. economy are taken into consideration, the actual cost of these emissions reduction programs could be quite a bit higher. In summary, there are several reasons why Professor Williams' cost estimates are biased downward.

274. For example, the federal-level regulatory approaches considered in EMF 24—renewable portfolio or clean energy portfolio standards, and enhanced fuel economy standards—were projected to cost twice as much to reduce GHG emissions in 2050 by 50% from 2005 levels compared to a perfectly implemented cap-and-trade system.[319]

275. Finally, Professor Jacobson cites 29 academic papers or reports in his Exhibit D relating to his claim that "[o]ther studies in the U.S. and abroad… provide parallel support for the ability

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[315] Leon E. Clarke et al., "Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise," *Energy Journal* 35, 2014, p. 9.

[316] U.S. Energy Information Administration, International Energy Statistics.

[317] For those scenarios the assumption is that "the most efficient policies for reducing GHG emissions generally allow for maximal 'when', 'where', and 'what' flexibility, i.e. allow banking and borrowing allowances across time, equalize the cost of abatement across all emissions sources, and cover all greenhouse gases." Allen A. Fawcett et al., "Overview of EMF 24 Policy Scenarios," *Energy Journal* 35, 2014, p. 44.

[318] These models were supposed to represent "the most efficient policies." Allen A. Fawcett et al., "Overview of EMF 24 Policy Scenarios," *Energy Journal* 35, 2014.

[319] Sugandha D. Tuladhar et al., "Interaction Effects of Market-Based and Command-and-Control Policies," *Energy Journal* 35, 2014, p. 77, Figure 10: Changes in Discounted PV of Welfare from 2010–2050 for Regulatory Mandates Compared to the Efficient Frontier (Trillions of 2010$). Although focusing mostly on the U.S. electricity sector, the range of transition rate and cost projections projected in the 2018 EMF 32 study across many models and scenarios are similar to those contained in the EMF 24 report, providing a further basis for comparison. See Jared R. Creason et al., "Effects of Technology Assumptions on US Power Sector Capacity, Generation and Emissions Projections: Results from the EMF 32 Model Intercomparison Project," *Energy Economics* 73, 2018, pp. 290–306. See also John E. Bistline et al., "Electric Sector Policy, Technological Change, and U.S. Emissions Reductions Goals: Results from the EMF 32 Model Intercomparison Project," *Energy Economics* 73, 2018, pp. 307–325.

to swiftly move away from fossil fuels."[320] He also states that "several of these published studies conclude that 100% renewable energy for all sectors by 2050 for France, the European Union, and globally is feasible."[321]

276. However, many of these articles (i) do not contemplate a transition to 100% renewables in the specific sector studied (e.g., electricity); (ii) do not consider decarbonization of all sectors; (iii) do not claim that the transition to renewables is costless for consumers; or (iv) do not claim that the transition can be achieved by a 2050 deadline. Table 5 replicates Professor Jacobson's Exhibit D and provides a clear breakdown as to the aspect (or aspects) in which these papers do not line up with Professor Jacobson's proposal.

[320] Jacobson Report, p. 6.
[321] Jacobson Report, pp. 6–7.

Table 5. Review of Decarbonization Studies Cited in Jacobson Report Exhibit D

No.	Publication	Change Modeled[1]	Areas that do not meet (✘) Dr. Jacobson's proposal				Reviewed by Heard[6]
			100% WWS[2]	All Energy Sectors[3]	At Same Cost[4]	By 2050[5]	
1	Mason, I.G., SC Page, and AG. Williamson, 2010. A 100% renewable electricity generation system for New Zealand utilizing hydro, wind, geothermal and biomass	100% renewable electricity in New Zealand		✘		✘	✘
2	Connolly, D. and BV. Mathiesen, 2014. A technical and economic analysis of one potential pathway to a 100% renewable energy system	100% renewable Ireland by 2050	✘				✘
3	Connolly, D., H. Lund, and BV. Mathiesen, 2016. Smart energy Europe: The technical and economic impact of one potential 100% renewable energy scenario for the European Union	100% renewable for all uses in Europe by 2050	✘				✘
4	Mathiesen, BV., H. Lund, and K. Karlsson, 2011. 100% Renewable energy systems, climate mitigation and economic growth	100% renewable for all uses by 2050	✘		✘		✘
5	Mathiesen, BV., et al., 2015. Smart energy systems for coherent 100% renewable energy and transport solutions	100% renewable for all uses	See note [7]				✘
6	Elliston, B., I. MacGill, and M. Diesendorf, 2013. Least cost 100% renewable electricity scenarios in the Australian National Electricity Market	100% renewable electricity		✘			✘
7	Elliston, B., I. MacGill, and M. Diesendorf, 2014. Comparing least cost scenarios for 100% renewable electricity with low emission fossil fuel scenarios in the Australian National Electricity Market	100% renewable electricity		✘			✘
8	Budischak, C., et al., 2013. Cost-minimized combinations of wind power, solar power and electrochemical storage, powering the grid up to 99.9% of the time	90-99.9% renewable electricity in US territory covered by PJM		✘			
9	MacDonald, A.E., C.T. Clack, et.al., 2016. Future cost-competitive electricity systems and their impact on US CO2 emissions	GHGs 78% below 1990 levels by 2030	✘	✘			
10	Williams, J.H., B. Haley, F. Kahrl, J. Moore, A.D. Jones, M.S. Torn, and H. McJeon, 2014. Pathways to deep decarbonization in the United States	GHGs 80% below 1990 levels by 2050	✘		✘		
11	United States White House, 2016. *U.S. Mid Century Strategy for Deep Decarbonization*	All greenhouse gas emissions 80%+ below 2005 by 2050.	✘		✘		
12	Hand, M.M., S. Baldwin, E. DeMeo, J.M. Reilly, T. Mai, D. Arent, G. Porro, M. Meshek, and D. Sandor, eds. 4 vols., 2012. Renewable Electricity Futures Study (Entire Report) National Renewable Energy Laboratory	Renewables could supply 80% of total U.S. electric generation by 2050	✘	✘	✘		
13	Mai, T., D. Mulcahy, MM Hand; and SF Baldwin, 2014. Envisioning a renewable electricity future for the United States	80% renewable electricity by 2050	✘	✘	✘		
14	Arent, D., J. Pless, et.al., 2014. Implications of high renewable electricity penetration in the U.S. for water use, greenhouse gas emissions, land-use, and materials supply	80% renewable electricity by 2050	✘	✘			

Table 5. Review of Decarbonization Studies Cited in Jacobson Report Exhibit D

			Areas that do not meet (✗) Dr. Jacobson's proposal				
No.	Publication	Change Modeled[1]	100% WWS[2]	All Energy Sectors[3]	At Same Cost[4]	By 2050[5]	Reviewed by Heard[6]
15	Mathiesen, B.V., H. Lund, et.al., 2015. Smart energy systems for coherent 100% renewable energy and transport solutions	100% renewable Denmark by 2050	Identical to article no. 5				
16	Connolly, D., BV Mathiesen, 2014. A technical and economic analysis of one potential pathway to a 100% renewable energy system	100% renewable Ireland by 2050	Identical to article no. 2				
17	Bogdanov, D. and C. Breyer, 2016. North-East Asian Super Grid for 100% renewable energy supply: Optimal mix of energy technologies for electricity, gas and heat supply options	100% renewable electricity in NE Asia by 2030		✗			
18	Parsons Brinckerhoff, 2009. Powering the Future: Mapping our Low-Carbon Path to 2050	80% reduction in CO2 in the UK by 2050	✗				
19	Schellekens, G., A. Battaglini, J. Lilliestam, J. McDonnell, and A. Patt, 2010. 100% renewable electricity: A roadmap to 2050 for Europe and North Africa	100% renewable electricity in Europe and N. Africa by 2050		✗			
20	Wright, M. and P. Hearps, 2010. Zero Carbon Australia Stationary Energy Plan	100% renewable stationary power for Australia in 10 years	✗				✗
21	Denis, A., Jotzo, F., et.al., 2014. Pathways to Deep Decarbonization in 2050: How Australia Can Prosper in a Low Carbon World	Net zero emissions in Australia by 2050	✗				
22	McKinsey & Company, KEMA, The Energy Futures Lab at Imperial College London, Oxford Economics, and European Climate Foundation, 2010. Roadmap 2050: A Practical Guide to a Prosperous, Low Carbon Europe, Vol 1.: Technical Analysis	Reduce GHGs 80% below 1990 levels by 2050	✗				
23	E3G, The Energy Research Centre of the Netherlands, and European Climate Foundation, 2010. Roadmap 2050: A Practical Guide to a Prosperous, Low Carbon Europe, Vol 2.: Policy Recommendations	Reduce GHGs 80% below 1990 levels by 2050	✗				
24	Zervos, A., C. Lins, and J. Muth, 2010. Re-thinking 2050: A 100% Renewable Energy Vision for the European Union	100% renewable energy for the EU by 2050	✗		✗		
25	Blake, L., P. Allen, et.al., 2013. Zero Carbon Britain: Rethinking the future	Net Zero GHG emissions in the UK by 2030	✗		✗		
26	Bataille, C., et al., 2015. Pathways to deep decarbonization in Canada	90% below baseline scenario in 2050	✗				
27	The négaWatt Association, 2017. The 2017-2050 négaWatt Scenario	100% renewable France by 2050	✗				
28	Aghahosseini, A., et al., 2018. Analysis of 100% renewable energy for Iran in 2030: Integrating solar PV, wind energy and storage	100% renewable Iran by 2030		✗			
29	Garcia-Olivares, A., et al., 2018. Transportation in a 100% renewable energy system	100% renewable global transportation		✗	✗	✗	

Source: Expert Report of Marc Jacobson filed April 6, 2018 ("Jacobson Report"), Exhibit D; Heard et al. 2017

Note:
[1] As listed in Jacobson Report, Exhibit D.
[2] Professor Jacobson proposes a 2050 technology portfolio limited to wind, water, and solar with limited geothermal and hydropower. The studies marked in this column utilize one or more technologies that Professor Jacobson excludes, resulting in less than 100% GHG mitigation.
[3] Professor Jacobson proposes 100% renewable energy for all energy sectors (residential, commercial, industrial and transportation). The studies marked in this column exclude or do not consider one or more of these energy sectors.
[4] Professor Jacobson proposes a 100% renewable energy system that has "similar or less than today's direct energy cost." The studies marked in this column indicate that costs would be higher than the business as usual scenario.
[5] Studies marked in this column either do not propose a timeline or do not meet the mitigation goal by 2050.
[6] Heard et al. 2017 concluded that for all of the 24 studies reviewed "the case for feasibility is inadequate for the formation of responsible policy directed at responding to climate change." Studies marked in this column were either reviewed, or a similar study with the same author was reviewed, by Heard et al. 2017.
[7] The paper indicated is not a transition analysis but rather a grid integration analysis. Additionally, the study only indicates that it's proposed system could "potentially pave the way to a bioenergy-free 100% renewable energy and transport system."

277. Furthermore, several of the studies cited in Professor Jacobson's Exhibit D (in addition to Professor Jacobson's study) were reviewed by Heard et al. 2017 who concluded that none of the studies reviewed provides convincing evidence that the basic criteria for feasibility can be met.[322] In particular, Heard et al. 2017 states that Professor Jacobson's work "depends strongly on extraordinary assumptions relating to electrification, energy storage, and flexibility in demand… [T]he results of such a simulation are likely to be meaningless because the underlying assumptions are unrealistic."[323]

278. A particular report cited by Professor Jacobson worth noting is the Renewable Electricity Futures Study,[324] which examines "the implications and challenges of renewable electricity generation levels—from 30% up to 90%, with a focus on 80%, of all U.S. electricity generation from renewable technologies—in 2050."[325] While the article concludes that this more modest proposal is possible, unlike Professor Jacobson it recognizes that there are significant demand-side costs associated with a transformation of the U.S. electricity system, including "average

[322] B. P. Heard et al., "Burden of Proof: A Comprehensive Review of the Feasibility of 100% Renewable Electricity Systems," *Renewable and Sustainable Energy Reviews* 76, 2017, pp. 1122–1133.
[323] B. P. Heard et al., "Burden of Proof: A Comprehensive Review of the Feasibility of 100% Renewable Electricity Systems," *Renewable and Sustainable Energy Reviews* 76, 2017, p. 1130.
[324] Maureen Hand et al., "Renewable Electricity Futures Study," National Renewable Laboratory, 2012 ("Renewable Electricity Futures Study").
[325] Renewable Electricity Futures Study, p. xvi.

annual retail electricity price increases of 0.8%–1.2% per year (2011–2050, in real dollar terms), compared to a rate of 0.3% per year in the baseline scenario."[326]

E. Addressing the Important Problem of Global Climate Change Requires Realistic Methods

279. Global climate change is an important problem to tackle, but it is also a challenging one. Many hundreds of analysts around the world have struggled with the physical, technological, and economic issues of creating a fully sustainable energy system, and many national laboratories, universities, and think tanks have focused on the issues of decarbonizing the energy system. Many journals, conference proceedings, conferences, and workshops report the findings of these endeavors. There is now a large body of literature that studies the problem of decarbonization and GHG mitigation.

280. But Professor Jacobson's proposal and to a lesser extent, Professor Williams' proposal, diverge greatly from the finding of these hundreds of analysts. Plaintiffs' experts' proposed energy systems, implementation timelines, and cost estimates deviate from the conclusions set forth in this large and growing literature. Unfortunately, many elements of the energy system transformations proposed by Professors Jacobson and Williams are not technically feasible, would require significant investment by consumers or businesses to invent, develop, and/or adopt new low-carbon energy technologies, would require major consumer behavioral change, would involve significant costs borne by the government or directly by energy users, and would require leaps in technology. Such transformations would likely require an unprecedented level of government intervention in the economy.

281. Addressing global climate change is an important objective, but it must be pursued realistically within the institutional framework of our economic and political system. Plaintiffs' experts have not demonstrated that their approaches are realistic or likely to succeed in practice.

[326] Renewable Electricity Futures Study, p. A-77.

Signed this 13th day of August, 2018.

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Assistant Professor	1971 - 1976
Associate Professor	1976 - 1980
Professor	1980 - 1996
Department Chairman	1991 - 1996
Department of Engineering-Economic Systems and Operations Research:	
Professor	1996 - 1999
Department Chairman	1996 - 1999
Department of Management Science and Engineering:	
Professor	2000 - current
Department of Economics:	

Affiliated Professor	1978 - ??
Cooperating Professor	1981 - 1982
Energy Modeling Forum:	
Director	1978 - 1984
Senior Advisory Panel Member	1988 - ??
Institute for Energy Studies:	
Chairman	1981 - 1985
Stanford Institute for Economic Policy Research (formerly, Center for Economic Policy Research):	
Director	1984 - 1986
Chairman: Energy, Natural Resources and the Environment Program	1984 - current
Steering Committee	1982 - ??
Senior Fellow	1998 - current
Public Policy Program:	
Steering Committee	1987-1991
Program in Earth Systems Science:	
Steering Committee	1992 - 2000
Freeman Spogli Institute for International Studies	
Senior Fellow (by Courtesy)	2005 - 2014
Steering Committee, Center for International Security and Cooperation:	1996 - 2014
Hoover Institution:	
Senior Fellow (by Courtesy)	2001 - current
Interdisciplinary Program in Environment and Resources:	
Executive Committee	2002 -2007
Precourt Energy Efficiency Center	
Director	2006 - 2018

U.S. Federal Energy Administration

Consultant	1974
Director, Office of Energy Systems	1974 - 1975
Director, Office of Quantitative Methods	1975
Director, Office of Energy Systems Modeling & Forecasting	1975 - 1976

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Council Chair -- 2018 – current
Economic and Allocation Advisory Committee, of California Air Resources Board,

2009 - 2010
Governor Schwarzenegger's Council of Economic Advisors, 2004 - 2011
Independent Review Panel, Public Interest Energy Research Program (California Energy Commission), First, Second, Third, Fourth Panels
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"The 2008 Award for Outstanding Contributions to the Profession of Energy Economics and to its Literature."

JOURNAL ARTICLES

"Quality, Commodity Hierarchies, and Housing Markets," *Econometrica*, Volume 42, No. 1, January 1974, pp. 147-167.

"Modeling Housing Markets: Commodity Hierarchies in a Spatial Setting," *Stanford Journal of International Studies*, Volume 10, Spring 1974, pp. 167-197.

"Housing Unit Maintenance and the Mode of Tenure," *Journal of Economic Theory*, Volume 8, No. 2, June 1974, pp. 111-138.

"A Commodity Hierarchy Model of the Rental Housing Market," *Journal of Urban Economics*, Volume 1, No. 3, July 1974, pp. 288-323.

"Economics of Depletable Resources: Market Forces and Intertemporal Bias," *Review of Economic Studies*, Volume 44, No. 1, February 1977, pp. 125-141. Reprinted in *The Economics of Exhaustible Resources*, Geoffrey Heal (ed.), Edward Elgar Publishing, Ltd., London, 1993.

"The Impact of the President's Proposed Gasoline Tax and Gas-Guzzler Tax on Gasoline Consumption," *DRI Energy Bulletin*, August, 1977, pp. 6-11.

"Methodologies for Petroleum Product Price Forecasting: A Review," with M. Therese Flaherty, *Topics in Energy*, Data Resources, Inc., September 1978, pp. 1-45.

"Optimal Growth with Depletable Resources," with P. C. Garg, *Resources and Energy*, Volume 1, No. 1, 1978, pp. 43-56.

"Energy Policy Models in the National Energy Outlook," with W. W. Hogan and M. H. Wagner, *Management Science*, Volume 10, 1978, pp. 37-62.

"The Energy Modeling Forum: Past, Present, and Future," with J. P. Weyant, *Journal of Business Administration*, Volume 10, Nos. 1 and 2, Fall, 1978 - Spring, 1979, pp. 295-320.

"Effects of Federal Policies on Gasoline Consumption," *Resources and Energy*, Volume 2, September 1979, pp. 3-26.

"Aggregate Elasticity of Energy Demand," principal author with EMF 4 Working Group members, *The Energy Journal*, Volume 2, No. 2, April 1981, pp. 37-75.

"World Oil: Preliminary Results from the Energy Modeling Forum Study," *Kvartals Skrift*, Bergen Bank: March-April 1981, pp. 161-179.

"Modeling For Insights, Not Numbers: The Experiences of the Energy Modeling Forum," with J. P. Weyant and H. G. Huntington, *Omega*, Volume 10, No. 5, November 1982, pp. 449-462.

"The Response of Energy Demand to Higher Prices: What Have We Learned?," *American Economic Review*, Volume 74, No. 2, May 1984, pp. 31-37; also published in *Global Energy Interactions*, R. K. Pachauri (ed.), Allied Publishers Private Limited, New Delhi, India, 1987, pp. 573-584.

"Analyzing Impacts of Potential Tax Policy Changes on U.S. Oil Security," *The Energy Journal*, with M. J. Boskin, Volume 6, August 1985, pp. 89-108.

"Changing World Oil Markets: What Should We Expect?," *Zeitschrift fur Energie Wirtschaft*, March 1986, pp. 73-74.

"On Economic Policy Responses to Disruptions: A Reply to Harry Saunders," with Bert Hickman and Hillard Huntington, *The Energy Journal*, October 1989, Vol 10 no. 4, pp. 189-198.

"Oil Import Fees With Exemptions: An Empirical Examination," *Resources and Energy*, March 1990, Vol. 11 no.3, pp. 215-239.

"The California Electricity Crisis: Lessons for the Future," *The Bridge*, Summer 2002, pp 23-31.

"An Energy Policy for the Twenty-first Century", *Hoover Digest*, 2005, No. 1. pp. 33-36.

"Low Carbon Growth: Our Ethical Responsibility", *Development Outreach*, World Bank Institute. February 2008.

"Learning-by-Doing and the Optimal Solar Policy in California", Arthur van Benthem, Kenneth Gillingham, and James Sweeney, *The Energy Journal*, 2008, Volume 29, No. 4, pp 131-151.

"Climate Speculations" Review of *Climatopolis: How Our Cities Will Thrive in the Hotter Future* by Matthew E. Kahn. *Stanford Social Innovation Review.* Winter 2011

"Recent trends in power system reliability and implications for evaluating future investments in resiliency", Peter H. Larsen, Kristina H. LaCommare, Joseph H. Eto, James Sweeney. *Energy* Volume 117, Part 1, 15 December 2016, Pages 29–46.
http://dx.doi.org/10.1016/j.energy.2016.10.063

"Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar," Christopher T. M. Clack, Staffan A. Qvist, Jay Apt, Morgan Bazilian, Adam R. Brandt, Ken Caldeira, Steven J. Davis, Victor Diakov, Mark A. Handschy, Paul D. H. Hines, Paulina Jaramillo, Daniel M. Kammen, Jane C. S. Long, M. Granger Morgan, Adam Reed, Varun Sivaram, James Sweeney, George R. Tynan, David G. Victor, John P. Weyants, and Jay F. Whitacre, *PNAS, Proceedings of the National Academy of Sciences*, vol. 114 no. 26, 6722–6727, doi: 10.1073/pnas.1610381114.

"Energy Efficiency: Still Low-hanging Fruit." *Hoover Digest*, 2017, No. 2, Spring, Hoover Institution

"How the West Was Wired" *Hoover Digest*, 2017, No. 4, Hoover Institution. Reprinted from *Sacramento Bee*. March 03, 2017.

BOOKS/MONOGRAPHS:

A Dynamic Theory of the Housing Market, Ph.D. dissertation, Department of Engineering-Economic Systems, Stanford University, 1971.

Handbook of Natural Resource and Energy Economics: A.V. Kneese and James L. Sweeney (ed.), North Holland,Volumes I and II, 1985. (Translated into Chinese, 2001.)

Macroeconomic Impacts of Energy Shocks: Bert G. Hickman, Hillard Huntington, James Sweeney (eds.), North Holland, 1987.

Potential Costs and Regulatory Burdens of the Energy Policy Act of 1992: Provisions for Alternative Fuel Vehicles. (Monograph) W. David Montgomery, Margaret Rhodes, and James Sweeney, DRI/McGraw-Hill and Charles River Associates, July 1993.

Handbook of Natural Resource and Energy Economics: A.V. Kneese and James L. Sweeney (ed.), North Holland, Volume III, 1993. (Translated into Chinese, 2001.)

Environmentally Significant Consumption: Research Directions: Paul C. Stern, Vernon W. Ruttan, Robert H. Socolow, and James L. Sweeney, editors. National Academy Press, Washington, D.C., 1997.

Trade and Industry Impacts of the Kyoto Protocol. W. David Montgomery and James L. Sweeney. (White Paper) The Business Roundtable. October 1999.

The California Electricity Crisis. James L. Sweeney. Hoover Institution Press. Stanford California. July 2002.

Energy Efficiency: Building a Clean, Secure Economy. Hoover Institution Press. Stanford California. 2016. Chinese Translation (translated by Sichuan Energy Internet Research Institute of Tsinghua University) 2017

CONTRIBUTIONS TO BOOKS:

Project Independence Report, contributor, Federal Energy Administration, November, 1974.

"A Mathematical Model of Housing Markets," *Proceedings: IEEE International Symposium on Circuits and Systems*, April 1974, pp. 468-472.

"Toward Housing Market Dynamics," *Proceedings; IEEE Conference on Decision and Control*, November 1974, pp. 814-817.

"Demand for Gasoline: Application of Commodity Hierarchy Theory," with D. B. Cato and M. E. Rodekohr, *Proceedings: Business and Economic Statistics Section*, American Statistical Association, 1975.

National Energy Outlook, major contributor, directed development of supply/ demand/price forecasts, Federal Energy Administration, February 1976.

"The Capital Stock Adjustment Process and the Demand for Gasoline; A Market Share Approach," with D. B. Cato and M. E. Rodekohr, in *Economic Dimensions and Energy Supply and Demand*, J. Kraft, B. Askin (eds.), Lexington Books, Lexington, Massachusetts, 1976.

"Energy Regulation: Solution or Problem?," in *Options for U.S. Energy Policy*, Institute for Contemporary Studies, San Francisco, 1977 pp. 179-209.

"The Demand for Gasoline: A Vintage Capital Model," in *Select Papers from Workshops on World Energy Supply and Demand*, International Energy Agency, Paris, 1978, pp. 240-277.

"A Price Forecasting System for Refined Petroleum Products," with G. R. Doenges, H. G. Huntington, and E. R. Novicky, a report submitted to the Department of Energy, Data Resources, Inc., JRB Associates, Inc., July 1978.

"Structural/Econometric Modeling of Gasoline Consumption," *Proceedings: Second Lawrence Symposium on Systems and Decision Sciences*, October 1978, pp. 241-252.

"Effects of Federal Policies on Gasoline Consumption," *Foresight: The Economic Impact of Energy Conservation*, Volume 3, Library of Congress, December 1978, pp. 241-225.

"New Car Efficiency Standards and the Demand for Gasoline," in *Advances in the Economics of Energy and Resources: The Structure of Energy Markets*, Volume 1, Robert Pindyck (ed.), JAI Press, Inc., Greenwich, Connecticut, 1979, pp. 105-133.

"U.S. Oil and Gas Supply Study," with J. P. Weyant, *Proceedings: AIME Annual Meeting*, Council of Economics, Las Vegas, Nevada, February 1980, pp. 73-84.

"The Energy Modeling Forum, an Overview", in *Validation and Assessment Issues of Energy Models*, Saul Gass (ed.), U.S. Department of Commerce/National Bureau of Standards Special Publication 569, February 1980, pp. 65-96.

Electric Load Forecasting: Probing the Issues with Models, Energy Modeling Forum Working Group 3, Volumes 1 and 2, Energy Modeling Forum, Stanford University, Stanford, California, March 1980.

"Overview," in *Electric Load Forecasting: Probing the Issues with Models*, EMF Report 3, Volumes 1 and 2, March 1980, pp. 5-15.

"Energy Problems and Policies," in *The Economy in the 1980's: A Program for Growth and Stability*, Institute for Contemporary Studies, San Francisco, Spring 1980, pp. 353-392.

"Energy Policies and Automobile Use of Gasoline," in *Selected Studies on Energy/Background Papers for Energy: The Next Twenty Years*, H. H. Landsberg, Spring 1980, pp. 93-125.

"Energy and Economic Growth: A Conceptual Framework," in *Symposium Papers: Energy Modeling and Net Energy Analysis*, Institute of Gas Technology, Chicago, 1978; also in *Mathematical Modeling of Energy Systems*, NATO Advanced Study Institute, Istanbul, Turkey, 1979; also in *Directions in Energy Policy: A Comprehensive Approach to Energy Resource Decision-Making*, B. Kursunoglu, A. Permutter (eds.), Fall 1979, pp. 115-140; also in Preprint of IBM *Systems Science Symposium: Modeling and Prediction of Large Scale Systems*, Nippon IBM Co., Ltd., September 1980, pp. 1-32 (volume title translated from Japanese).

"The Energy Modeling Forum: Past, Present, and Future," with J. P. Weyant, in *Energy Policy - The Global Challenge*, P. N. Nemetz (ed.) Institute for Research on Public Policy, Fall 1979, pp. 292-320; also in *Energiemodelle für die Bundesrepublik Deutschland*, A. Voss, K. Schmitz, (eds.), Verlag TUV Rheinland Koln, Spring 1980, pp. 149-167.

"Energy Modeling Forum 5: U.S. Oil and Gas Supply," in *Energy Modeling III: Dealing with Energy Uncertainty*, April 1981, pp. 283-303.

"The Theory and Practice of Energy Aggregation," with A. B. Borison and T. F. Wilson, in *Aggregate Elasticity of Energy Demand*, Volume 2, Energy Modeling Forum.

"Price and Quantity Change Decomposition for Aggregated Commodities," in *Aggregate Elasticity of Energy Demand*, Volume 2, Energy Modeling Forum.

"Energy Modeling Forum 4: Aggregate Elasticity of Energy Demand," with W. W. Hogan and J. P. Weyant, *Proceedings: Conference on Alternative Energy Sources*.

"Resource Depletion, Research and Development and the Social Rate of Discount: A Commentary and Extension," in *The Rate of Return for Energy Investment*, Robert Lind, Martin Greenberger, (eds.).

"Model Comparison for Energy Policy and Planning," in *Energy Policy Planning*, Bayraktar, Cherniavsky, Laughton, and Ruff, (eds.), NATO.

"The Relationship Between Energy Use and the Economy," in *Energy Independence for the United States*, Nake M. Kamrany, The Newport Foundation, 1981. Also published in *U.S. Options for Energy Independence*, Nake M. Kamrany, D. C. Heath & Co., 1982.

World Oil, Energy Modeling Forum Working Group 6, Energy Modeling Forum, Stanford University, Stanford, California, January 1982.

"Energy Model Comparison: An Overview," in *Large-Scale Energy Models -- Prospects and Potential*, Westview Press, Inc., Boulder, CO, 1983, pp. 191-217.

"Price Asymmetry in the Demand for Energy," with David Fenichel, *Energy Demand Prospects & Trends*, Paul Stevens (ed.) Camelot Press Ltd. Southhampton, Great Britain, 1987, pp. 48-70. Also in *Papers and Proceedings of the Eighth Annual North American Conference, the Changing World Economy*, International Association of Energy Economists, Cambridge, MA, May, 1987, pp. 218-222.

"Principles of Geographic Market Definition," *Manual on Antitrust Economics*, Economics Committee Antitrust Division, American Bar Association.

"Optimal Control and Time Consistent Equilibria in Dominant Firm/Competitive Fringe Dynamic Games," with Patricio del Sol, *IFAC/IFORS/IAEE International Symposium on Energy Systems, Management, and Economics*, October 1989, Tokyo.

"Production Costs for Alternative Liquid Transportation Fuels," *Methanol As An Alternative Fuel Choice: An Assessment*, Wilfrid Kohl (ed.), The Johns Hopkins Foreign Policy Institute, Washington D.C., 1990.

Fuels to Drive our Future, Committee on Production Technologies for Liquid Transportation Fuels, National Academy Press, Washington D.C. 1990. Principal Author, Chapter 3 and Appendix D.

The National Energy Modeling System, Committee on the National Energy Modeling System, National Research Council, National Academy Press, Washington D.C. 1992. Principal Author, Chapter 3: "NEMS Architecture."

"Economic Theory of Depletable Resources: An Introduction," Chapter 17 in *Handbook of Natural Resource and Energy Economics*, Volume III, A.V. Kneese and J.L. Sweeney (editors), North Holland, 1993.

"Natural Resource Economics," in *The Social Science Encyclopedia*, Edition 2, Routledge, London 1996.

"Energy Economics", In: Neil J. Smelser and Paul B. Baltes, Editor(s)-in-Chief, *International Encyclopedia of the Social & Behavioral Sciences*, Pergamon, Oxford, 2001, Pages 4513-4520 (www.sciencedirect.com/science/article/B7MRM-4MT09VJ-PS/2/17641810797ce56d07449fd00b951033)

"Natural Resource Economics," *The Social Science Encyclopedia*, Edition 3, Routledge, London 2004.

California Public Interest Energy Research: Independent PIER Panel Report, Independent PIER Panel. California Council on Science and Technology, March 2000.

California Public Interest Energy Research: Independent PIER Panel Final Report, Independent PIER Panel. California Council on Science and Technology, March 2001.

Energy Research at DOE: Was It Worth It? Committee on Benefits of DOE R&D in Energy Efficiency and Fossil Energy. National Academy Press, Washington, D.C. July 17, 2001.

Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards. Committee on Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards. National Academy Press, Washington, D.C. July 30, 2001.

The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs. Committee on Alternatives and Strategies for Future Hydrogen Production and Use. National Academy Press, Washington, D.C. July 2004

Prospective Evaluation of Applied Energy Research and Development at DOE (Phase One): A First Look Forward. Committee on Prospective Benefits of DOE's Energy Efficiencey and Fossil Energy R&D Programs (Phase One.) National Academy Press, Washington, D.C. 2005.

"California Electricity Restructuring, the Crisis, and its Aftermath;" Chapter 10 in *Electricity Market Reform: An International Perspective*, Perry Shioshansi and Wolfgang Pfaffenberger (eds.) Elsevier, April 2006

"Hydrogen for Light Duty Vehicles: Opportunities and Barriers in the United States", Chapter 17 in *Human-Induced Climate Change: An Interdisciplinary Assessment*; Michael Schlesinger (Ed.), Cambridge University Press, 2007

National Security Consequences of U.S. Oil Dependency. Independent Task Force Report No. 58, Council on Foreign Relations, 2006.

California Action Plan for Transportation Energy Security. California Strategic Transportation Energy Partnership. CalStart, January 2007.

Prospective Evaluation of Applied Energy Research and Development at DOE (Phase Two.) Committee on Prospective Benefits of DOE's Energy Efficiencey and Fossil Energy R&D Programs (Phase Two). National Academy Press, Washington, D.C. 2007.

Liquid Transportation Fuels from Coal and Biomass: Technological Status, Costs, and Environmental Impact.) America's Energy Future Panel on Alternative Liquid Transportation Fuels; National Academy of Sciences; National Academy of Engineering; National Research Council. National Academy Press, Washington, D.C. 2009.

America's Energy Future: Technology and Transformation. Committee on America's Energy Future; National Academy of Sciences; National Academy of Engineering; National Research Council. National Academy Press, Washington, D.C. 2009.

"Market Failure and the Structure of Externalities", Kenneth Gillingham and James Sweeney in *Harnessing Renewable Energy in Electric Power Systems,* Boaz Moselle, Jorge Padilla, and Richard Schmalensee, (eds.), RFF Press, August 2010.

“Barriers to Implementing Low Carbon Technologies”, Kenneth Gillingham and James Sweeney in *Climate Change Economics,* Vol. 3, No. 4, World Scientific Publishing Company 2012

OP/ED PIECES/Videos:

“Integrate western power grid to reduce emissions, energy costs”, *Sacramento Bee*. March 03, 2017. http://www.sacbee.com/opinion/op-ed/soapbox/article135866278.html

“Increased Efficiency: Our Best Source of Clean Energy” POLICYed Video https://www.policyed.org/intellections/increased-efficiency, 2017

“An energy resource any U.S. president could love”, *The Hill*. November 30, 2016. http://thehill.com/blogs/congress-blog/energy-environment/308170-cheap-clean-and-easily-accessible-an-energy-resource

SELECTED WORKING PAPERS, REPORTS:

"The Logic of Efficiency Standards and Their Influence on Gasoline Consumption," with M. E. Rodekohr and D. B. Cato, Working Paper, Federal Energy Administration, March 1975.

The U. S. Oil and Gas Supply, Energy Modeling Forum Working Group 5. Energy Modeling Forum, Stanford University, 1981.

"Time Inconsistency and the Advantage of Not Committing: The Importer of an Exhaustible Resource," with Patricio del Sol, Center for Economic Policy Research Working Paper, Stanford California, October 1988.

"Price Oscillations in Oligopoly," with William Comanor, Center for Economic Policy Research Publication No. 181, Stanford California, January 1990.

"Mandates for Alternative Fuels: A Policy Analysis," with David Montgomery, Charles River Associates, September 1991.

"Review of Transportation Fuels Analysis and Policy Recommendations in California Energy Commission: *California Energy Plan,*" with David Montgomery, April 1992.

"Mandating a Transition to Alternative Transportation Fuels: Economic, Environmental and Energy Security Implications," with David Montgomery, June 1992.

"Gasoline Taxes: An Economic Assessment," Prepared for the Office of Technology Assessment, U.S. Congress, September 1993.

"Evaluation of the EPA's Proposal for Renewable Oxygenates," May 1994. Prepared for The American Petroleum Institute.

“Agricultural Damage of Common Crops and Externalities Associated with Bread Consumption,” May 1997, with W. David Montgomery, J. Eric Bickel, Graydon Barz, Wenlong Weng, and Fehmi Ashaboglu. EES&OR Department Working Paper.

“Tradable Fuel Economy Credits. Analysis and Text Extended from Chapter 5 of *Impact and Effectiveness of Corporate Average Fuel Economy Standards,”* August 12, 2001.

“Regulating Fuel Economy: Corporate Average Fuel Economy Standards,” *Policy Brief*, Stanford Institute for Economic Policy Research, March 2003.

“Deconstructing the Rosenfeld Curve,” Anant Sudarshan and James Sweeney, June 2008, http://peec.stanford.edu/library

“Analysis of Measures to Meet the Requirements of California’s Assembly Bill 32” Precourt Energy Efficiency Team, September 2008. http://peec.stanford.edu/library
“Allocating Emissions Allowances Under a California Cap-and-Trade Program: Recommendations to the California Air Resources Board and California Environmental Protection Agency from the Economic and Allocation Advisory Committee” California Air Resources Board. March 2010. Authors: Justin Adams, Vicki Arroyo, Matthew Barger, James K. Boyce, Dallas Burtraw, James Bushnell, Robert Fisher, Richard Frank, Larry Goulder, Dan Kammen, Christopher R. Knittel, Stephen Levy, Joe Nation, Nancy E. Ryan, Nancy Sidhu, James L. Sweeney

“Assessing Changes in the Reliability of the US Electric Power System.,” Peter H. Larsen, Kristina LaCommare, Joseph Eto, James Sweeney. No. LBNL-188741. Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA (United States), 2015.

“Petroleum Market Advisory Committee Final Report.” December 2014 to November 2016”. California Energy Commission CEC-200-2017. Severin Borenstein, Kathleen Foote, Dave Hackett, Amy Jaffe, James Sweeney. September 2017.

James L Sweeney
Litigation in which testimony was offered in the past four years

Phillips 66 Company, Successor-In-Interest to Tosco Corporation, And HDI-Gerling Industrie Versicherung Ag, Formerly Known As Gerling Konzern Allgemeine Versicherungs – Ag,
Arbitration
John Ellison, Reed Smith LLP
Worked on behalf of Phillips 66
Written Testimony submitted, 2014

United States Enrichment Corporation v. Entergy Services, Inc., and Entergy Nuclear Fuels Company
Arbitration re Enriched Product Agreements
Worked on behalf of USEC
William Phillips, Covington & Burling LLP
Report and Hearing Testimony, 2015

Melissa D. Duflock, v. Chevron Corporation,
Petroleum Royalties dispute
Worked on behalf of Chevron
Filed Declaration 2016
Deposition, 2016

The Enpex Corporation v. San Diego Gas and Electric Company
Dispute re Electricity Crisis Era proposal for a PPA or a turnkey plant.
Case No. 37-2016-00034956-CU-BT-CTL
Superior Court of the State of California, For the County of San Diego
Worked on behalf of The Enpex Corporation
David Kleinfeld, Thorsnes Bartolotta Mcguire LLP
Deposition, 2018

Documents Relied Upon by Professor James L. Sweeney

Pleadings

Federal Defendants' Answer to First Amended Complaint for Declaratory and Injunctive Relief, *Kelsey Cascadia Rose Juliana et al., Plaintiffs, v. United States et al., Defendants*, January 13, 2017

First Amended Complaint for Declaratory and Injunctive Relief, *Kelsey Cascadia Rose Juliana et al., Plaintiffs, v. The United States of America et al., Defendants*, September 10, 2015

Expert Reports / Declarations

Declaration of James Gustave "Gus" Speth in Support of Plaintiffs' Response in Opposition to Defendants' Motion for Summary Judgment, June 27, 2018

Expert Report of Eric Rignot, Ph.D., April 11, 2018

Expert Report of James E. Hansen, Ph.D., April 13, 2018

Expert Report of James H. Williams, Ph.D., April 13, 2018

Expert Report of Joseph E. Stiglitz, Ph.D., April 13, 2018

Expert Report of Mark Jacobson, Ph.D., April 6, 2018

U.S. Code

26 U.S.C. § 45a

42 U.S.C., §7111

42 U.S.C., §7151

Publicly Available Reports

A. Denis et al., "Pathways to Deep Decarbonization in 2050 – How Australia Can Prosper in a Low Carbon World," The Australian report of the Deep Decarbonization Pathways Project of the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations, 2014

A. Zervos et al., "Re-Thinking 2050: A 100% Renewable Energy Vision for the European Union," *European Renewable Energy Council*, 2010, http://fft.szie.hu/mnt/Re-thinking%202050.pdf

Airbus Global Market Forecast, "Growing Horizons: 2017/2036," 2017

Boeing Report, "Current Market Outlook: 2017-2036," June 19, 2017

C. Bataille et al., "Pathways to Deep Decarbonization in Canada," *SDSN – IDDRI*, 2015, http://deepdecarbonization.org/wp-content/uploads/2015/09/DDPP_CAN.pdf

California Environment Protection Agency, Air Resources Board Report, "California's Advanced Clean Cars Midterm Review," January 18, 2017

Cédric Philibert, "Renewable Energy for Industry: From Green Energy to Green Materials and Fuels," International Energy Agency Report, 2017

Congressional Budget Office Report, "Effects of Federal Tax Credits for the Purchase of Electric Vehicles," September 2012, https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/electricvehiclesone-col.pdf

Eric Wood et al., "National Plug-In Electric Vehicle Infrastructure Analysis," U.S. Department of Energy Report, September 2017

Federal Energy Administration, "Project Independence," Project Independence Report, November 1974, https://catalog.hathitrust.org/Record/000686195

Federal Energy Regulatory Commission Report, "Hydropower Primer," February 2017, https://www.ferc.gov/legal/staff-reports/2017/hydropower-primer.pdf

Gus Schellekens et al., "100% Renewable Electricity: A Roadmap to 2050 for Europe and North Africa," 2010, http://www.sefep.eu/activities/projects-studies/2011-05-11-100-%20renewables.pdf

International Iron Metallics Association Report, "Ore-Based Metallics: Adding Value to the EAF," May 2017, http://seaisi.org/seaisi2017/file/file/full-paper/Session7B%20Paper2.pdf

IPCC Report, "Climate Change 2014 Impacts, Adaptation, and Vulnerability Summary for Policymakers," 2014

IPCC Report, "Climate Change 2014 Synthesis Report Summary for Policymakers," 2014

"Iron and Steel," Energy Technology Systems Analysis Programme, International Energy Agency, May 2010

Jane C. S. Long, "California's Energy Future: The View to 2050," California Council on Science and Technology Report, May 2011

Lisa J. Hanle et al., "CO_2 Emissions Profile of the U.S. Cement Industry," U.S. Environmental Protection Agency Report, undated

Matthew Wright and Patrick Hearps, "Australian Sustainable Energy: Zero Carbon Australia Stationary Energy Plan," *The University of Melbourne Energy Research Institute*, 2010, http://media.bze.org.au/ZCA2020_Stationary_Energy_Report_v1.pdf

Maureen Hand et al., "Renewable Electricity Futures Study," National Renewable Laboratory, 2012

Michael D. Fenton, "Iron and Steel," U.S. Geological Survey Mineral Commodities Summaries, January 2015, https://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/mcs-2015-feste.pdf

National Renewable Energy Laboratory, NREL/TP-461-7281, "The Super Efficient Refrigerator Program: Case Study of a Golden Carrot Program," July 1985, http://www.nrel.gov/docs/legosti/old/7281.pdf

Paul Allen et al., "Zero Carbon Britain: Rethinking the Future," *Centre for Alternative Technology*, 2013, http://www.zerocarbonbritain.org/images/pdfs/ZCBrtflo-res.pdf

"Policy Options For Stabilizing Global Climate," U.S. Environmental Protection Agency Report, 1990

"Powering the Future: Mapping Our Low-Carbon Path to 2050," *Parsons Brinckerhoff*, 2009, http://hub.globalccsinstitute.com/sites/default/files/publications/138013/powering-future-mapping-low-carbon-path-2050.pdf

"Report of the conference of the parties on its first session, held at Berlin from 28 March to 7 April 1995," United Nations Framework Convention on Climate Change, 1995, https://unfccc.int/resource/docs/cop1/07a01.pdf

"Restoring the Quality of Our Environment," The White House, 1965

"Roadmap 2050: A Practical Guide to a Prosperous, Low-Carbon Europe, Vol. 1: Technical Analysis," *European Climate Foundation*, 2010, http://www.roadmap2050.eu/attachments/files/Volume1_fullreport_PressPack.pdf

"Roadmap 2050: A Practical Guide to a Prosperous, Low-Carbon Europe, Vol. 2: Policy Recommendations," *European Climate Foundation*, 2010, http://www.roadmap2050.eu/attachments/files/Volume2_Policy.pdf

SGI Aviation Report, "Aircraft Retirements and Part-Out: Effective Use of Existing Trends and Opportunities in the Market," September 15, 2016

Solar Energy Industries Association Report, "Solar Market Insight Report 2016 Year In Review"

"The 2017-2050 négaWatt Scenario," *Association négaWatt*, 2017, https://negawatt.org/IMG/pdf/negawatt-scenario-2017-2050_english-summary.pdf

The Pew Charitable Trusts Report, "Power Surge: Energy Security and the Department of Defense," January 2014

Trieu Mai et al., "Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States," Department of Energy Report #DE-AC36_08GO28308, 2018, https://www.nrel.gov/docs/fy18osti/71500.pdf

U.S. Energy Information Administration Report, "Annual Energy Outlook 2018," February 6, 2018

U.S. Energy Information Administration Report, "Annual Energy Outlook 2014"

U.S. Energy Information Administration Report, "Annual Energy Review 2011"

U.S. Energy Information Administration Report, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018," March 2018, https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

U.S. Environmental Protection Agency, 2018, "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016," Table ES-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (MMT CO2 Eq.)

U.S. Internal Revenue Service Bulletin: 2009–48, November 30, 2009, https://www.irs.gov/irb/2009-48_IRB#NOT-2009-89.

UNEP Report, "The Emissions Gap Report 2017," 2017

UNFCCC Report, Carbon Pricing Leadership Coalition, "Report of the High-Level Commission on Carbon Prices," May 29, 2017

United States White House, "United States Mid-Century Strategy for Deep Decarbonization," 2016, https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf

World Energy Council Report, "World Energy Trilemma 2016," 2016

Academic Literature / Books

A. Aghahosseini et al., "Analysis of 100% Renewable Energy for Iran in 2030: Integrating Solar PV, Wind Energy and Storage," *International Journal of Environmental Science and Technology* 15, 2018, pp. 17–36

Alexander E. MacDonald et al., "Future Cost-Competitive Electricity Systems and Their Impact on US CO_2 Emissions," *Nature Climate Change* 6, 2016, pp. 526–531

Allen A. Fawcett et al., "Overview of EMF 24 Policy Scenarios," *Energy Journal* 35, 2014

Antonio García-Olivares et al., "Transportation in a 100% Renewable Energy System," *Energy Conversion and Management* 158, 2018, pp. 266–285

Arthur van Benthem et al., "Learning-by-Doing and the Optimal Solar Policy in California," *Energy Journal* 29, no. 3, 2008, pp. 1–26

B. P. Heard et al., "Burden of Proof: A Comprehensive Review of the Feasibility of 100% Renewable Electricity Systems," *Renewable and Sustainable Energy Reviews* 76, 2017, pp. 1122–1133

B. V. Mathiesen et al., "Smart Energy Systems for Coherent 100% Renewable Energy and Transport Solutions," *Applied Energy* 145, 2015, pp. 139–154

Ben Elliston et al., "Comparing Least Cost Scenarios for 100% Renewable Electricity with Low Emission Fossil Fuel Scenarios in the Australian National Electricity Market," *Renewable Energy* 66, 2014, pp. 196–204

Ben Elliston et al., "Least Cost 100% Renewable Electricity Scenarios in the Australian National Electricity Market," *Energy Policy* 59, 2013, pp. 270-282

Brian Vad Mathiesen et al., "100% Renewable Energy Systems, Climate Mitigation and Economic Growth," *Applied Energy* 88, 2011, pp. 488–501

Christoph Böhringer et al., "Introduction to the EMF 29 Special Issue on the Role of Border Carbon Adjustment in Unilateral Climate Policy," *Energy Economics* 34, sup. 2, pp. S95–S96

Christopher T. M. Clack et al., "Supporting Information for the Paper 'Evaluation of a Proposal for Reliable Low-Cost Grid Power with 100% Wind, Water, and Solar,'" *PNAS*, 2017, pp. 1–13

Colleen L.S. Kantner et al., "Impact of the EISA 2007 Energy Efficiency Standard on General Service Lamps," *Berkeley Lab*, LBNL-1007090, January 2017, https://www.eenews.net/assets/2017/05/04/document_gw_04.pdf

Cory Budischak et al., "Cost-Minimized Combinations of Wind Power, Solar Power and Electrochemical Storage, Powering the Grid Up to 99.9% of the Time," *Journal of Power Sources* 225, 2013, pp. 60–74

D. Connolly et al., "Smart Energy Europe: The Technical and Economic Impact of one Potential 100% Renewable Energy Scenario for the European Union," *Renewable and Sustainable Energy Reviews* 60, 2016, pp. 1634–1653

David Connolly and Brian Vad Mathiesen, "A Technical and Economic Analysis of One Potential Pathway to a 100% Renewable Energy System, *International Journal of Sustainable Energy Planning and Management* 01, 2014, pp. 7–28

Dmitrii Bogdanov and Christian Breyer, "North-East Asian Super Grid for 100% Renewable Energy Supply: Optimal Mix of Energy Technologies for Electricity, Gas and Heat Supply Options," *Energy Conservation and Management* 112, 2016, pp. 176–190

Doug Arent, "Implications of High Renewable Electricity Penetration in the U.S. for Water Use, Greenhouse Gas Emissions, Land-Use, and Materials Supply," *Applied Energy* 123, 2014, pp. 368–377

"Energy Research at DOE, Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000," Committee on Benefits of DOE R&D on Energy Efficiency and Fossil Energy, Board on Energy and Environmental Systems, Division on Engineering and Physical Sciences, National Research Council (Washington, DC: National Academy Press, 2001)

F. Grobler and R.C.A. Minnitt, "The Increasing Role of Direct Reduced Iron in Global Steelmaking," *Journal of the South African Institute of Mining and Metallurgy*, March/April 1999, pp. 111–116

I. G. Mason et al., "A 100% Renewable Electricity Generation System for New Zealand Utilising Hydro, Wind, Geothermal and Biomass Resources," *Energy Policy* 38, 2010, pp. 3973–3984

International Energy Agency, *Energy Statistics Manual* (Paris: IEA Publications, 2005)

J. H. Williams et al., "Pathways to Deep Decarbonization in the United States," The U.S. Report of the Deep Decarbonization Pathways Project of the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations, 2014

James L. Sweeney, *Energy Efficiency: Building a Clean, Secure Economy* (Stanford, CA: Hoover Institution Press, 2016)

Jared R. Creason et al., "Effects of Technology Assumptions on US Power Sector Capacity, Generation and Emissions Projections: Results from the EMF 32 Model Intercomparison Project," *Energy Economics* 73, 2018, pp. 290–306

Jessica Jewell et al., "Limited Emission Reductions from Fuel Subsidy Removal Except in Energy-Exporting Regions," *Nature* 554, 2018, pp. 229–233

John C.B. Cooper, "Price Elasticity of Demand for Crude Oil: Estimates for 23 Countries," *OPEC Review* 27, no. 1, 2003, pp. 1–8

John E. Bistline et al., "Electric Sector Policy, Technological Change, and U.S. Emissions Reductions Goals: Results from the EMF 32 Model Intercomparison Project," *Energy Economics* 73, 2018, pp. 307–325

Joseph E. Aldy et al., "Investment Versus Output Subsidies: Implications of Alternative Incentives for Wind Energy," December 2016

Kenneth Gillingham and James Sweeney, "Market Failure and the Structure of Externalities," in *Harnessing Renewable Energy*, ed. Boaz Moselle et al. (New York: Routledge, 2010)

Leon E. Clarke et al., "Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise," *Energy Journal* 35, 2014, pp. 9–31

Mark D. Bowles, *"The 'Apollo' of Aeronautics: NASA's Aircraft Energy Efficiency Program 1973 – 1987"* (Washington, DC: NASA, 2010), https://www.nasa.gov/pdf/601247main_ApolloAeronautics-ebook.pdf

Mark Z. Jacobson et al., "100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States," *Energy & Environmental Science* 8, 2015, Supplemental Information, pp. 1–105

Mark Z. Jacobson et al., "100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States," *Energy & Environmental Science* 8, no. 7, 2015, pp. 2093–2117

Mark Z. Jacobson et al., "Low-Cost Solution to the Grid Reliability Problem with 100% Penetration of Intermittent Wind, Water, and Solar for All Purposes," *Proceedings of the National Academy of Sciences* 112, no. 49, 2015, pp. 15060–15065

N. Gregory Mankiw, *Principles of Economics*, 3rd Edition (Mason, OH: Thomson South-Western, 2004)

Peter Erickson et al., "Effect of Subsidies to Fossil Fuel Companies on United States Crude Oil Production," *Nature Energy* 2, 2017, pp. 891–898

Raphael J. Heffron, "What is Energy Law," in *Energy Law: An Introduction* (Springer International Publishing, 2015), pp. 1–10

Shaojian Wang et al., "The Relationship Between Economic Growth, Energy Consumption, and CO_2 Emissions: Empirical Evidence from China," *Science of The Total Environment* 542, 2016, pp. 360–371

Sugandha D. Tuladhar et al., "Interaction Effects of Market-Based and Command-and-Control Policies," *Energy Journal* 35, 2014, pp. 61–88

Thomas Covert et al., "Will We Ever Stop Using Fossil Fuels?," *Journal of Economic Perspectives*, 2016, pp. 1–26

Trieu Mai et al., "Envisioning a Renewable Electricity Future for the United States," *Energy* 65, 2014, pp. 374–386

William D. Nordhaus, "A Review of the *Stern Review on the Economics of Climate Change*," *Journal of Economic Literature* 45, no. 3, 2007, pp. 686–702

Yoichi Kaya and Keiichi Yokoburi, *Environment, Energy, and Economy: Strategies for Sustainability* (United States of America: United Nations University Press, 1997)

Public Press, Web Pages, and Other Publicly Available Materials

"Airbus Aircraft 2018 Average List Price (USD Millions)," *Airbus*, http://www.airbus.com/content/dam/corporate-topics/publications/backgrounders/Airbus-Commercial-Aircraft-list-prices-2018.pdf, accessed May 9, 2018

"A380 Superjumbo Lands in Sydney," *BBC*, October 25, 2007, http://news.bbc.co.uk/2/hi/business/7061164.stm, accessed May 9, 2018

"About Boeing Commercial Airplanes," *Boeing*, http://www.boeing.com/company/about-bca/#/prices, accessed May 9, 2018

"About the Solar Energy Technologies Office," *Solar Energy Technology Offices*, https://www.energy.gov/eere/solar/about-solar-energy-technologies-office, accessed August 3, 2018

"About Us," *Bonneville Power Administration*, https://www.bpa.gov/news/AboutUs/Pages/default.aspx

"About Us," *Office of Nuclear Energy*, https://www.energy.gov/ne/about-us

"Advanced Technology Vehicle Sales Dashboard," *Auto Alliance*, https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/

Al Gore, "Kyoto Climate Change Conference," *Clinton Whitehouse Archive*, December 8, 1997, https://clintonwhitehouse3.archives.gov/WH/EOP/OVP/speeches/kyotofin.html, accessed August 3, 2018

Alex McEachern, “Hybrids: What is the Difference Between Traditional and Plug-in?,” *Electric Vehicle News*, June 8, 2012, https://www.fleetcarma.com/hybrids-what-is-the-difference-between-traditional-and-plug-in/

“Alternative Fueling Station Counts by State,” *U.S. Department of Energy*, August 4, 2018, https://www.afdc.energy.gov/fuels/stations_counts.html, accessed August 4, 2018

Bamini Chakraborty, “Paris Agreement on Climate Change: US Withdraws as Trump Calls it ‘Unfair,’” *Fox News*, June 1, 2017, http://www.foxnews.com/politics/2017/06/01/trump-u-s-to-withdraw-from-paris-climate-pact-calls-it-unfair-for-america.html, accessed August 3, 2018

“Becoming a UNFCCC delegate: what you need to know,” *International Institute for Environment and Development*, 2016, http://pubs.iied.org/pdfs/17385IIED.pdf, accessed August 3, 2018

Bryan Walsh, “Why the Climate Bill Died,” *Time*, July 26, 2010, http://science.time.com/2010/07/26/why-the-climate-bill-died/, accessed August 3, 2018

“California Auto Outlook: Comprehensive Information on the California Vehicle Market,” *California New Car Dealers Association*, February 2018, https://www.cncda.org/wp-content/uploads/California-Covering-4Q-2017-1.pdf

“Carbon Storage Research,” *Department of Energy*, https://www.energy.gov/fe/science-innovation/carbon-capture-and-storage-research, accessed August 3, 2018

“Climate Change: Obama Unveils Clean Power Plan,” *BBC*, August 3, 2015, http://www.bbc.com/news/world-us-canada-33753067, accessed August 3, 2018

“Congress Votes Largest Tax Cut in History,” *CQ Almanac 1975* (Washington, DC: Congressional Quarterly, 1976), http://library.cqpress.com/cqalmanac/cqal75-1213141

“Crude Oil Prices: West Texas Intermediate (WTI) - Cushing, Oklahoma,” *Economic Research Federal Reserve Bank of St. Louis*, August 1, 2018, https://fred.stlouisfed.org/series/DCOILWTICO

“DRI Production,” *International Iron Metallics Association*, https://www.metallics.org/dri-production.html, accessed July 13, 2018

Daniel J. Weiss, “Anatomy of a Senate Climate Bill Death,” *Center for American Progress*, October 12, 2010, https://www.americanprogress.org/issues/green/news/2010/10/12/8569/anatomy-of-a-senate-climate-bill-death, accessed August 3, 2018

David Blackmon, “Oil And Gas Tax Provisions Are Not Subsidies For ‘Big Oil’,” January 2, 2013, *Forbes*, https://www.forbes.com/sites/davidblackmon/2013/01/02/oil-gas-tax-provisions-are-not-subsidies-for-big-oil/#6bd8d0ca52e8, accessed August 12, 2018

David Bowed, “Airbus Will Reveal Plan for Super-Jumbo: Aircraft would Seat at Least 600 People and Cost Dollars 8bn to Develop,” *The Independent*, June 4, 1994, https://www.independent.co.uk/news/business/airbus-will-reveal-plan-for-super-jumbo-aircraft-would-seat-at-least-600-people-and-cost-dollars-8bn-1420367.html, accessed on May 9, 2018

David Byrne, “Australia’s Energy Trilemma Explained,” *The University of Melbourne*, July 3, 2017, https://pursuit.unimelb.edu.au/articles/australia-s-energy-trilemma-explained, accessed August 6, 2018

David Rosenbaum, “Clinton Backs Off Plan for New Tax on Heat in Fuels,” *New York Times*, June 9, 1993, https://www.nytimes.com/1993/06/09/us/clinton-backs-off-plan-for-new-tax-on-heat-in-fuels.html, accessed August 3, 2018

David S. Hilzenrath, “Miscalculations, Lobby Effort Doomed BTU Tax Plan,” *Washington Post*, June 11, 1993, https://www.washingtonpost.com/archive/business/1993/06/11/miscalculations-lobby-effort-doomed-btu-tax-plan/d756dac3-b2d0-46a4-8693-79f6f8f881d2/?noredirect=on&utm_term=.0283a25da88e, accessed August 3, 2018

Deon Daugherty, “Limit Crude Imports: Perhaps Eisenhower Was on to Something,” *Rigzone*, January 25, 2016, https://www.rigzone.com/news/oil_gas/a/142660/column_limit_crude_imports_perhaps_eisenhower_was_on_to_something/?all=hg2, accessed August 3, 2018

"Drive clean and save," *California Clean Vehicle Rebate Project*, https://cleanvehiclerebate.org/eng.

"EERE Timeline," *Office of Energy Efficiency & Renewable Energy*, https://www.energy.gov/eere/timeline/eere-timeline

"Energy Units and Calculations Explained," U.S. Energy Information Administration, https://www.eia.gov/energyexplained/index.php?page=about_energy_units, accessed August 11, 2018

"Eight States Plan for 3.3 Million Zero-Emission Vehicles by 2025," *United States Department of Energy*, October 30, 2018, https://www.energy.gov/eere/vehicles/articles/eight-states-plan-33-million-zero-emission-vehicles-2025

"Federal Tax Credits for All-Electric and Plug-in Hybrid Vehicles," *U.S. Department of Energy*, https://www.fueleconomy.gov/feg/taxevb.shtml

"Final Overview of the §1603 Program," *U.S. Treasury*, March 1, 2018, https://www.treasury.gov/initiatives/recovery/Pages/1603.aspx

George Bush, "Statement on Signing the Instrument of Ratification for the United Nations Framework Convention on Climate Change," *The American Presidency Project*, October 13, 1992, http://www.presidency.ucsb.edu/ws/?pid=21611

"Government Energy Management," *Office of Energy Efficiency and Renewable Energy*, https://www.energy.gov/eere/efficiency/government-energy-management, accessed August 3, 2018

"History of Major Energy Policy Landmarks," Department of Geography, PennState, https://www.e-education.psu.edu/geog432/node/116, accessed August 11, 2018

"History of the Boeing 787," *Seattle Times*, Associated Press, June 23, 2009, http://old.seattletimes.com/html/nationworld/2009373399_apusboeing787historyglance.html, accessed May 9, 2018

House Resolution 1027, 114th Congress, 2015

House Resolution 1086, 102nd Congress, 1991

House Resolution 2202, 114th Congress, 2015

House Resolution 309, 114th Congress, 2015

House Resolution 4283, 114th Congress, 2015

House Resolution 4805, 101st Congress, 1990

House Resolution 6049, 110th Congress, 2009

House Resolution 804, 103rd Congress, 1993

House Resolution 972, 114th Congress, 2015

"How much tax do we pay on a gallon of gasoline and a gallon of diesel fuel?" U.S. Energy Information Administration, https://www.eia.gov/tools/faqs/faq.php?id=10&t=10, accessed August 3, 2018

https://www.youtube.com/watch?v=oKRJAlT4dqw

"IMF Projects Venezuela Inflation Will Hit 1,000,000 Percent in 2018," *Reuters*, July 23, 2018, https://www.reuters.com/article/us-venezuela-economy/imf-projects-venezuela-inflation-will-hit-1000000-percent-in-2018-idUSKBN1KD2L9, accessed August 13, 2018

"Indicative Scales of contributions from parties to the Convention and the Kyoto Protocol for the biennium 2016-2017," *United Nations Climate Change Secretariat*, December 2015, https://unfccc.int/sites/default/files/scale.pdf

James Brooke, "The Earth Summit; President, in Rio, Defends His Stand on Environment," *New York Times*, June 13, 1992, https://www.nytimes.com/1992/06/13/world/the-earth-summit-president-in-rio-defends-his-stand-on-environment.html, accessed August 6, 2018

Jason Furman and Gene Sperling, "Reducing America's Dependence on Foreign Oil as a Strategy to Increase Economic Growth and Reduce Economic Vulnerability," August 29, 2013, *Obama White House Archives*, https://obamawhitehouse.archives.gov/blog/2013/08/29/reducing-america-s-dependence-foreign-oil-strategy-increase-economic-growth-and-redu, accessed August 2, 2016

Jim Gorzelany, "Which (Of Only A Few) Hybrids Make Financial Sense," *Forbes*, August 26, 2016, https://www.forbes.com/sites/jimgorzelany/2016/08/26/cheap-gas-means-few-hybrids-make-financial-sense-to-own/#1c23cdc85d7c

Juliet Ellperin, "U.S. Firms Look Ahead to Emissions Cuts Overseas," *Washington Post*, October 3, 2004, http://www.washingtonpost.com/wp-dyn/articles/A2936-2004Oct2.html, accessed August 3, 2018

"Know the Legislation," *Price on Carbon*, https://priceoncarbon.org/business-society/history-of-federal-legislation/, accessed August 3, 2018

Laurie Goering, "Clinton Signs Pact on Global Warming," *Chicago Tribune*, November 13, 1998, http://articles.chicagotribune.com/1998-11-13/news/9811130120_1_greenhouse-gas-emissions-greenhouse-gases-global-warming, accessed August 3, 2018

Lisa Friedman and Brad Plumer, "E.P.A. Announces Repeal of Major Obama-Era Carbon Emissions Rule," *New York Times*, October 9, 2017, https://www.nytimes.com/2017/10/09/climate/clean-power-plan.html, accessed August 3, 2018

Marisa Garcia, "Future Proof: Fuel Cell Systems Could Power Aircraft Cabin Parts," *APEX*, February 5, 2018, https://apex.aero/2018/02/05/fuel-cell-systems-power-commercial-aircraft-cabin-parts, accessed May 9, 2018

Michael D. Shear, "Trump Will Withdraw U.S. from Paris Climate Agreement," *New York Times*, June 1, 2017, https://www.nytimes.com/2017/06/01/climate/trump-paris-climate-agreement.html, accessed August 13, 2018

National Resources Revenue Data, U.S. Department of the Interior, https://revenuedata.doi.gov/explore/, accessed August 3, 2018

"Percentage Depletion," *Energy Tax Facts*, http://energytaxfacts.com/wp-content/uploads/2017/10/Fact-Sheet-Percentage-Depletion.pdf

Peter Pae, "Airbus Giant-Jet Gamble OKd in Challenge to Boeing," *Los Angeles Times*, December 20, 2000, http://articles.latimes.com/2000/dec/20/news/mn-2453, accessed May 9, 2018.

"Price on Carbon," https://priceoncarbon.org/

Richard Nixon, "Address to the Nation About Policies to Deal with the Energy Shortages," *The American Presidency Project*, November 7, 1973, http://www.presidency.ucsb.edu/ws/?pid=4034, accessed August 3, 2018

Samantha Masunaga, "No Flying Tesla? That's Because Electric Planes Are a Steeper Challenge than Electric Cars," *L.A. Times*, September 9, 2016, http://www.latimes.com/business/la-fi-electric-aircraft-20160830-snap-story.html

"Saving Energy and Money with Appliances and Equipment Standards in the United States," *U.S. Department of Energy*, January 2007, https://www.energy.gov/sites/prod/files/2017/01/f34/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-011917_0.pdf

Senate Resolution 1151, 109th Congress, 2005

Senate Resolution 139, 108th Congress, 2003

Senate Resolution 1548, 114th Congress, 2015

Senate Resolution 2399, 114th Congress, 2015

Senate Resolution 280, 110th Congress, 2007

Senate Resolution 98, 105th Congress, 1997

Steve Everley, "Stanford's Jacobson Spins Energy Misinformation (100% renewables fantasy)," *MasterResource*, 2016, https://www.masterresource.org/renewable-energy-and-jobs/stanfords-jacobson-spins-misinformation-in-the-energy-debate-100-renewables-fantasy/, accessed August 3, 2018

Steven Greenhouse, "Clinton's Economic Plan: The Energy Plan; Fuels Tax: Spreading the Burden," *New York Times*, February 18, 1993, https://www.nytimes.com/1993/02/18/us/clinton-s-economic-plan-the-energy-plan-fuels-tax-spreading-the-burden.html, accessed August 3, 2018

Stuart Burns, "Hydrogen to Replace Coking Coal in the Reduction of Iron Ore Steelmaking? Maybe One Day," *Metal Miner*, February 13, 2017, https://agmetalminer.com/2017/02/13/hydrogen-to-replace-coking-coal-in-the-reduction-of-iron-ore-in-steelmaking-maybe-one-day/

"Summary Charts," California State Budget – 2018–19, http://www.ebudget.ca.gov/2018-19/pdf/Enacted/BudgetSummary/SummaryCharts.pdf

Tanya Somanader, "President Obama: The United States Formally Enters the Paris Agreement," *Obama Whitehouse Archives,* September 3, 2016, https://obamawhitehouse.archives.gov/blog/2016/09/03/president-obama-united-states-formally-enters-paris-agreement, accessed August 3, 2018

Ted Nordhous and Michael Shellenberger, "Getting Real on Climate Change," *The American Prospect*, December 2008, https://thebreakthrough.org/blog/PDF/Getting%20Real%20on%20Climate%20Change.pdf

"The Cement Industry Is the Most Energy Intensive of All Manufacturing Industries," U.S. Energy Information Administration, July 1, 2013, https://www.eia.gov/todayinenergy/detail.php?id=11911

Tim Kelly, "Dreamliner Carries Its First Passengers and Boeing's Hopes," *Reuters*, October 26, 2011, https://www.reuters.com/article/us-dreamliner/dreamliner-carries-its-first-passengers-and-boeings-hopes-idUSTRE79P02Q20111026, accessed May 9, 2018

Tom Balcerek, "Turning Away from Blast Furnaces Still Leaves Problems for Steel Industry," *Platts*, October 20, 2015, blogs.platts.com/2015/10/20/blast-furnaces-problems-steel-industry/

"U.S. Federal Government Energy Costs at Lowest Point Since Fiscal Year 2004," U.S. Energy Information Administration, https://www.eia.gov/todayinenergy/detail.php?id=33152, accessed August 3, 2018

"United Nations Framework Convention on Climate Change," United Nations, 1992, https://unfccc.int/resource/docs/convkp/conveng.pdf

"US Nuclear Policy," *World Nuclear Association*, May 2018, http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power-policy.aspx, accessed August 3, 2018

"US R&D Spending at All-Time High, Federal Share Reaches Record Low," *American Institute of Physics*, November 8, 2016, https://www.aip.org/fyi/2016/us-rd-spending-all-time-high-federal-share-reaches-record-low

Valerie Richardson, "White House Defends Obama Evading Senate on Paris Climate Deal," *Washington Times*, August 29, 2016, https://www.washingtontimes.com/news/2016/aug/29/obama-will-bypass-senate-ratify-paris-climate-acco/, accessed August 3, 2018

"What are the Federal Reserve's objectives in conducting monetary policy?," *Federal Reserve*, June 13, 2018, https://www.federalreserve.gov/faqs/money_12848.htm, accessed August 3, 2018

"What is the U.S. Commitment in Paris?," *State of the Planet*, December 11, 2015, http://blogs.ei.columbia.edu/2015/12/11/what-is-the-u-s-commitment-in-paris/, accessed August 3, 2018

Zack Colman and Nick Sobczyk, "House Republican Will Introduce $23 Carbon Tax Next Week," *eenews.net*, July 17, 2018, https://www.eenews.net/climatewire/2018/07/17/stories/1060089315, accessed August 6, 2018

Press Releases

Office of Governor Edmund G. Brown Jr. Press Release, "Governor Brown Takes Action to Increase Zero-Emission Vehicles, Fund New Climate Investment," January 26, 2018, https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/

Vattenfall Press Release, "Vattenfall and Cementa Focusing on Zero Emissions," June 29, 2017, https://group.vattenfall.com/press-and-media/news--press-releases/pressreleases/2017/vattenfall-and-cementa-focusing-on-zero-emissions

White House Press Release, "Fact Sheet: President Obama's Blueprint for a Clean and Secure Energy Future," March 15, 2013, https://www.whitehouse.gov/the-press-office/2013/03/15/fact-sheet-president-obama-s-blueprint-clean-and-secure-energy-future, accessed August 3, 2018

White House Press Release, "Global Climate Change Policy Book," 2002, https://georgewbush-whitehouse.archives.gov/news/releases/2002/02/climatechange.html, accessed August 3, 2018

Analyst Reports

"Lazard's Levelized Cost of Energy Analysis – Version 11.0," *Lazard*, November 2017, https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf

"U.S. Solar Market Insight," *GTM Research*, https://www.seia.org/research-resources/solar-market-insight-report-2016-year-review

Presentation

California Environment Protection Agency Presentation, "California's ZEV Regulation for 2018 and Subsequent Model Year Vehicles," 2016, pp. 1–51

Data Sources

Appliance Standards Awareness Project

"CVRP Rebate Statistics," *California Clean Vehicle Rebate Project*

Federal Reserve Bank of St. Louis

hybridcars.com

National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division, ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_gl.txt, accessed August 3, 2018

U.S. Department of Energy, Alternative Fuels Center

U.S. Department of Transportation, "Highway Statistics 2000"

U.S. Department of Transportation "Highway Statistics 2015"

U.S. Energy Information Administration, 2014 MECS Survey Data, October 2017, Table 1.1 First Use of Energy for All Purposes (Fuel and Nonfuel), 2014.

U.S. Energy Information Administration, International Energy Statistics

U.S. Energy Information Administration, "July 2018 Monthly Energy Review"

U.S. Energy Information Administration, "May 2018 Monthly Energy Review"

Any other documents or materials cited in this report.